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Lappel Bank and Fagbury Flats Compensatory Measures Site Suitability for Waterfowl

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EXECUTIVE SUMMARY

Following the loss to port developments of a total of 42 ha of mudflats and 12 ha of saltmarsh from Lappel Bank on the Medway estuary and Fagbury Flats on the Orwell estuary, compensation measures are to be provided under the EU Habitats Directive. These mudflats were important feeding and roosting areas for a number of species of waders and wildfowl - Dark-bellied Brent Geese, Shelduck, Oystercatcher, Ringed Plover, Grey Plover, Lapwing, Knot, Dunlin, Curlew, Redshank and Turnstone, and held a few Cormorants, Mallard and Sanderling.

Estuaries in the south-east of England hold internationally and nationally important numbers of waterfowl, the Medway being internationally important for Dark-bellied Brent Geese, Shelduck, Ringed Plover, Grey Plover, Dunlin and Redshank, and nationally important for Oystercatcher; the Orwell holding internationally important numbers of Redshank and nationally important numbers of Dark-bellied Brent Geese, Shelduck, Ringed Plover and Dunlin.

The aim of this report is to define the habitat requirements of the waterfowl displaced by these port developments, and then draw up a short-list from nine candidate sites according to their suitability as possible compensation sites in terms of these preferences.

The dietary and physical habitat preferences of the displaced species of waterfowl have been investigated through literature review. The distribution of Dark-bellied Brent Geese in winter is strongly tied to saltmarsh and intertidal *Zostera* beds. The distribution of other waterfowl are correlated with estuarine sediment types, these relationships being due to the association between the invertebrate prey of the waterfowl and sediment. Most wintering waterfowl show preferences for muddy sediments on sheltered extensive intertidal mudflats, although some - Oystercatcher, Grey Plover, Ringed Plover and Turnstone prefer sandier, slightly more exposed areas.

Disturbance, particularly from water sports and hunting, has a negative effect on feeding and roosting birds, especially in winter, and can affect feeding and roosting site choice.

The nine sites offered as compensation have been preliminarily assessed in respect of their suitability for wintering waterfowl, and the distributions of the relevant bird species on the estuaries concerned. For any site to provide suitable compensation for both Lappel Bank and Fagbury Flats, it will have to attain at least three times the mean south-east estuary waterfowl density and thus will require good initial design and management. The most suitable site is likely to be Boyton Marsh which is large, sheltered, well situated and relatively free from disturbance. Weymarks Marsh (Option 1) is large and would be expected to be muddy with attendant high waterfowl densities. The third most suitable option is St Mary's Marsh which is also large, but being more exposed is likely to be sandier and therefore have lower invertebrate biomasses. Blacketts Marsh is also promising for if it were to attain the waterfowl densities of adjoining areas, it alone could provide adequate compensation for the displaced birds. The remaining sites, dependent on the development of suitable substrata, are only likely to provide partial compensation areas if a split compensation strategy is preferred.

It is recommended that any outstanding information on intertidal sediments, vegetation and invertebrate benthos from each candidate site is collated to confirm these preliminary findings, and most importantly that the BTO's predictive models based on estuary sediment and morphology are run to increase the precision of the estimates of the number of waterfowl that each short-listed candidate site is likely to hold post-management.

1. INTRODUCTION

Following the loss to port developments of Lappel Bank on the Medway estuary, and Fagbury Flats on the Orwell estuary, compensation measures are to be provided under the scope of Article 6.4 of the Habitats Directive. This will probably involve the creation of suitable areas of mudflat by the removal of sea defences. The areas lost comprised a total of 42 ha of mudflats and 12 ha of saltmarsh, which provided a mixture of feeding and roosting habitats for a number of waterfowl species. In order to provide suitable compensation areas for the birds displaced from these sites, it is first necessary to know what factors influence site selection and usage by waterfowl. Wintering waterfowl use intertidal estuarine and coastal areas for both feeding and roosting. Choice of feeding sites is primarily governed by the availability of key prey items, whose distributions are in turn determined by the presence of suitable environmental conditions (chiefly sediment type and organic content). To predict waterfowl distribution it is thus necessary to know the environmental preferences of birds and their prey. Furthermore, since roosting is also an energetically important factor for wintering waterfowl, their site use will be partially determined by the availability of suitable high water roosting sites.

This report aims to:

1. Through literature review, determine those environmental factors important to waterfowl when selecting and using winter feeding and roosting sites;

2. Relate these habitat requirements to the proposed compensation sites, to determine the suitability of each as replacement habitat for the bird species displaced.

2. ESTIMATES OF WATERFOWL NUMBERS DISPLACED BY DEVELOPMENT

2.1 Count Methodology: Roost Versus Low Tide Counts

Two methods are widely used to survey waterfowl in the United Kingdom by the Wetland Bird Survey (WeBS): counts primarily of waterfowl roosts made at high tide(Core Counts), and counts primarily of feeding waterfowl made two hours either side of low tide (Low Tide Counts). The numbers of birds recorded by the two methods are similar at the whole estuary scale (Musgrove 1998), but can be very variable at a finer spatial scale.

Roosts can concentrate thousands of birds in a small area and are largely chosen as a result of being relatively free of disturbance and having good visibility to allow approaching predators to be spotted. The number of waterfowl recorded in a count section at high tide is very dependent on whether roosts have formed on it and therefore numbers can be much higher if roosts are present (*eg* Fagbury Flats: Section 2.4). The exact positioning of roosts will also vary with local management, waterfowl making use of a field to roost during one winter may avoid the area the next if the vegetation has become denser as a result of changed site management, for example. Low Tide Counts tend to be more constant from one winter to the next as the birds distribute themselves according to feeding conditions which tend to be fairly constant in south-east England estuaries with low tidal ranges (Rehfisch *et al.* 1997).

Feeding conditions are more likely to determine the presence of waterfowl at a site than roosts as the latter have rarely been demonstrated to be limiting. Furthermore, replacement roosts can be created relatively easily (Burton *et al.* 1996). Therefore, when assessing the likely impact to waterfowl of habitat change in an area, Low Tide Counts are likely to be of greater value than roost counts as local roosts are likely to be able to relocate themselves in the vicinity or substitute roosts can be created, whereas the loss of feeding grounds is more likely to impact permanently on the number of waterfowl that a site can support (Moser 1988, Austin & Rehfisch 1998) and artificial feeding grounds are more complex to recreate.

2.2 Count Methodology: Estimating Site Importance by Mean Versus Peak Counts

Mean counts of waterfowl on a count section give an indication of the average number of birds that it can support over a specified time period. Peak counts are more prone to inflate the importance of a count section. A single large flock of waterfowl could potentially only be present for a short period of time on a count section, but if it coincides with the section being counted, the section would appear from its peak count to hold large numbers of waterfowl. Its mean count could be construed to be more realistic.

It is important that when the success of the chosen site(s) is determined at a later date, the monitoring scheme(s) should be as representative of the scheme(s) used to originally determine the importance of the two sites lost, Lappel Bank and Fagbury Flats.

2.3 Predictive Methodology

Overall mean and peak densities of each species of waterfowl were calculated from data gathered during up to 14 counts made over two winters on 247 count units in six estuaries in South East England. The overall mean densities were simple averages of the mean densities calculated for each count unit. The overall peak density for each species was taken to be the highest mean density recorded over two winters on a single count unit. The overall peak densities for different species will tend to be recorded on different count units as the habitat requirements of different species are rarely the same. No count unit is likely to hold an overall density of all waterfowl i.e. the sum of the peak densities of each of the species from any of the 247 count sections.

These overall mean and peak values were then used to estimate the densities (and thus numbers) of waterfowl that could be found on the candidate sites once they have been managed to become estuarine habitat. The estimates for each candidate site based on the mean densities will be broadly accurate if the habitat created on the candidate sites after management becomes similar to that found in the region; some species being found in higher than average densities, others in lower than average densities. To attain high overall numbers of waterfowl, management of a site should aim to make it more attractive to species such as dunlin, for this is the species that can be found at the highest density in UK estuaries. The estimates based on the peak densities are likely to be overestimates, possibly by a considerable margin, of the numbers of birds that will be found on the candidate sites. Even after management, it is highly unlikely that the sites could attract peak densities of each species.

The accuracy of the estimates of the numbers of waterfowl likely to make use of the candidate sites could be improved by making use of specially developed models (Holloway *et al.* 1996, Austin *et al.* 1996). These models developed specifically to make it possible to estimate the impact of estuarine habitat change on waterfowl densities would give more accurate estimates of the waterfowl numbers on the candidate sites for the following reason. The Phase I estimates based on overall mean densities assume an estuary that is typical of those in South East England and take no account of differences between estuaries. The models, on the other hand, take into account estuary morphology (shape), geographical position, tidal range and fetch, factors that are important in helping determine waterfowl densities. For example, a long, thin estuary with a small tidal range will hold higher densities of waterfowl than a wider estuary with a greater tidal range. This is because wide estuaries with large tidal amplitudes are subject to large amounts of tidal energy from the sea which travels up the estuary relatively unconstrained by a narrow estuary mouth. This energy regularly resuspends any fine sediment particles and does not allow muddy intertidal areas to form; the resulting sandy estuary will hold fewer waterfowl as invertebrate densities tend to be lower in sand than mud. The models also account for other factors such as disturbance. All things being equal, a long, thin estuary is more likely to be subject to higher relative levels of disturbance than a short, squat estuary as the disturbance comes from the sides, whether by humans on footpaths or raptors. In the theoretical example of two estuaries with the same surface area, the short squat estuary has clearly more area out of reach of a raptor that relies on surprise attacks when hunting than the long, thin estuary (Figure 2.1). Similarly the long, thin estuary would be more likely to be affected by human disturbance. It is recommended that these models be run in Phase II to help improve the accuracy of the estimates of the number of waterfowl that the short-listed candidate sites are likely to hold, and thus help with the selection procedure.

2.4 Lappel Bank

Lappel Bank, on the Medway estuary, was a 22 ha intertidal mudflat adjacent to the port of Sheerness. Port development in 1994/5 led to the reclamation of this area and loss of an important winter feeding site for a large number of waterfowl.
Comparisons of the mean peaks of five years Low Tide Count data for the important bird species

utilising the site in winter prior to development, and the available High Tide Count data for some of those species for the whole Medway estuary for the same five-year period show that a number of species utilised Lappel Bank at a higher density than the estuary as a whole before loss of the site (Table 2.1.2 - species codes are defined in Table 2.1.1). These were Shelduck, Oystercatcher, Ringed Plover, Dunlin, Curlew, Redshank and Turnstone. Of these species, the Medway currently holds internationally important winter numbers of Shelduck, Ringed Plover, Dunlin and Redshank, and nationally important winter numbers of Oystercatcher (Waters *et al.* In prep.) (Table 2.1.3). Whilst these two counts were obtained by slightly different methods, one by low tide counts on mudflats, and one by high tide roost counts, they do illustrate the importance of Lappel Bank as a feeding area, and that compensatory areas should be capable of harbouring as many key bird species as possible while holding a similar number of individuals as those extrapolated from current whole estuary densities. In addition to this, comparison of the Lappel Bank bird numbers with those obtained by similar low tide methodology for the whole Medway estuary in the winter of 1996/97 indicates that those key species had also attained much greater densities than are currently observed throughout the estuary. Thus, in compensating for the loss of the site, these specific densities should be considered as well as the current whole estuary data, to ensure sufficient replacement habitat is provided.

2.5 Fagbury Flats

Fagbury Flats, previously an area of 32 ha of intertidal mussel beds, mudflats and saltmarsh, is situated just north of Felixstowe port in Suffolk, and was lost to further port development in 1995.

Comparison of the mean five-year peak High Tide Count for the important bird species using Fagbury Flats in the winters 1990/91 to 1994/95 (before site development) with the available High Tide Counts for the whole Orwell estuary spanning this period show that the densities of most species using Fagbury Flats were higher than for the estuary as a whole (Table 2.2.1). These were Dark-bellied Brent Geese, Oystercatcher, Ringed Plover, Grey Plover, Dunlin and Turnstone. Of the species displaced by the loss of Fagbury Flats, the Orwell estuary holds internationally important numbers of Redshank and nationally important numbers of Dark-bellied Brent Geese, Shelduck, Ringed Plover and Dunlin (Waters *et al.* In prep.) (Table 2.1.3). Comparison of the latest low tide counts for the whole Orwell estuary (WeBS 1996/97) with the Fagbury Flats High Tide Count also shows the Flats to have had higher densities of birds (Table 2.2.1). This is partly because the earlier Fagbury Flats and whole Orwell counts were high tide roost counts as opposed to the more recent low tide feeding count. This is perhaps indicative of the role Fagbury Flats played as a roosting site for birds, particularly Dunlin, not only from the Orwell but from the whole Deben/Stour Orwell area (Evans 1997). However, comparison of the 1988/89 mean winter low tide count on Fagbury Flats (NRA 1993) with the 1996/97 mean winter low tide count on the whole Orwell also shows that densities of Dark-bellied Brent Geese, Ringed Plover, Grey Plover, Dunlin, Redshank and Turnstone were higher on Fagbury Flats than those recently observed at the whole estuary level.

2.6 Great Britain Population Indices

National and regional population indices indicate that since the development of Fagbury Flats and Lappel Bank, populations of the majority of affected wader species have increased or remained constant, both in the local 'Anglian region' and nationally (Figure 2.3.1) (Austin *et al.* 1997; Austin & Rehfisch, In prep.). Oystercatcher have declined in the Anglian region, but nationally their population has remained stable. Knot have shown a similar pattern, whilst Curlew have declined both locally and nationally. These regional population trends should be taken into account when considering the success of the compensation for the loss of Fagbury Flats and Lappel Bank, although Dark-bellied Brent Geese have shown a decline in national population index of 36% between the winters of 1991/92 and 1995/96, but then populations are stable in Essex and Thames, and increased in Kent during this period (Cranswick *et al.* 1997).

3. HABITAT REQUIREMENTS AND PREFERENCES OF WATERFOWL

3.1 Literature Review

The physical characteristics of habitats influence the distributions of animals within them and therefore the availability of food to predators. Thus, habitat quality is a good indicator of reliable feeding conditions and is therefore one of the most important influences on bird populations. Habitat also determines the suitability of roost sites, but this is not thought to be as critical in limiting bird distributions. Food is a critical factor in habitat selection by birds (Fretwell & Lucas 1970; Goss-Custard 1977; Goss-Custard *et al.* 1995a & b), which tend to feed in areas of high prey densities to optimise energy expenditure. Differences in substratum composition have been shown to influence the abundance and availability of plants and invertebrates to birds (Myers *et al.* 1980; Quammen 1982). Yates *et al.* (1993) showed that the densities of major waterfowl prey species were correlated with the sediment composition on intertidal mudflats (Table 3.1.1). Furthermore, Yates *et al.* (1993), and Goss-Custard *et al.* (1991) showed that prey density accounts for much of the variation in bird densities on mudflats. Yates *et al.* (1996) found that the sediment composition of estuaries could be predicted with a high degree of confidence from simple measures of estuary shape, tidal range and shore width and fetch (Table 3.1.2). Thus, the distribution of birds may also be predicted by estuary topography (Austin *et al.* 1996). The strong influence of prey density, and therefore sediment type, on bird distribution in winter estuarine feeding areas has led to a body of work describing the physical habitat preferences of wintering waterfowl (Table 3.1.3).

The early winter distribution of Dark-bellied Brent Geese is linked to the distribution of their preferred food plants - eel-grass of the genus *Zostera* - on intertidal mudflats, but equally important later in the winter and early spring is the availability of saltmarsh habitat and its vegetation once *Zostera* beds are grazed out (Ganter & Ebbinge 1997). Spring saltmarsh has been shown to be particularly important to migrating geese at staging areas in the Waddensea, where up to 30% body mass increases have been recorded pre-migration (Ganter & Ebbinge 1997). It is likely that saltmarsh in the UK in late winter is equally important in the birds' preparation for migration to their Siberian breeding grounds. Furthermore, Dark-bellied Brent Geese show a high degree of site fidelity to their spring saltmarsh sites (St Joseph 1979; Prokosch 1984).

High Shelduck densities have been associated with sediments with a high proportion of mud, in estuaries with large areas of mud. In addition, Shelduck density has been correlated with areas of low tidal range and low fetch within narrow estuaries. Since these physical conditions are conducive to the settlement of finer mud and silt particles (Goss-Custard & Yates 1992; Yates *et al.* 1996; Rehfisch *et al.* 1997) the link between Shelduck and muddy sediment is supported.

Mallard numbers are higher on sediments with a high proportion of muddy sand, and on estuaries with a low total area of saltmarsh (Austin *et al.* 1996).

Oystercatcher densities have been linked with more exposed estuaries having large areas of sandy or muddy sand sediments and saltmarsh (Austin *et al.* 1996; Yates *et al.* 1993; Yates & Goss-Custard 1991). This not only agrees with the sediment preferences of their major infaunal prey species such as *Cardium edule*, but also with the high exposure and nutrient loads required by *Mytilus edulis*, another favoured prey species.

Ringed Plover, Knot, Dunlin, Curlew and Redshank all show marked preference for narrow sheltered estuaries with large areas of muddy sediments. Grey Plover, however, are more associated with wide, muddy sand shores on estuaries with large areas of mudflats.

3.2 Bird Distributions in the Context of Estuarine Morphology and Sediments

Much of the above information is derived from two parallel studies, Holloway *et al.* (1996) and Austin *et al.* (1996), which examined in detail the relationships between distributions of winter feeding birds on British estuaries and the distribution and composition of sediments and a range of topographical factors.

3.2.1 Relationships Between Bird Densities and Sediment Type on Mudflats in South East England

Holloway *et al.* (1996) examined the usage of intertidal areas by waterfowl on 27 estuaries throughout Britain. Estuaries were divided into a number of discrete count areas and the numbers of waterfowl and the sediment/habitat type for each count unit determined. A total of 14 counts were obtained for each count unit over two winters, each count being made two hours either side of low tide. From these data it has been possible to calculate the mean density of each bird species observed on each of a range of sediment types on six south-east England estuaries (Breydon Water, Blyth, Alde, Deben, Swale & Pagham Harbour) (Table 3.2.1.1). This re-analysis was restricted to south-eastern estuaries, since these most closely resemble the estuaries on which habitat has been lost. Densities of Brent Geese were calculated separately from WeBS Low Tide Counts (Table 3.2.1.2) as sufficient data were not available in Holloway *et al.* (1996).

Shelduck and Wigeon were observed mainly on muddy count units, with some observations of birds in mixed areas, these also containing a proportion (by area) of muddy sediment. Oystercatcher were seen in a variety of habitats, perhaps reflecting the patchy nature of some of their prey species (particularly *Mytilus edulis* beds). The highest mean densities were observed on sandy or muddy sand areas, with the highest maximum density on sand. The relatively high densities of Oystercatcher on mixed and 'other' (= non-sediment) areas again reflecting the patchy nature of some food species. Ringed Plover were seen on a much wider variety of habitats, feeding on mud, sand and mixed areas, with the exception of saltmarsh. The peak observed density was, however, on mud. The highest mean and peak densities of Grey Plover were observed on sand and mixed habitat count units, with lower densities seen on mud. The highest mean densities of Knot were in count units containing muddy sand and sand, although the highest peak density was recorded on mud. Dunlin were most prevalent in muddy count units, but were observed on all mudflat sediment types in relatively large numbers. Curlew and Redshank were observed in the highest densities on mud and mixed substrata, whilst Turnstone were most prevalent on mixed substrata.

3.2.2 Correlations Between Whole Estuary Bird Density and Environmental Variables - Country-wide Analysis

Following on from Holloway *et al.* (1996), Austin *et al.* (1996) used these detailed data to correlate whole estuary bird densities with a range of sediment cover and estuarine morphology variables (Tables 3.2.2.1 & 3.2.2.2) for their respective estuaries. These correlations were made on a country-wide basis, incorporating 25 British estuaries (Tables 3.2.2.3 & 3.2.2.4). These analyses were repeated for sub-groups containing west coast and south and east coast estuaries, because it was previously known that there is a general tendency for estuaries on the east and south coasts to be muddier than those on the west coast of Britain, and that these regional differences influence the apparent relationships between estuaries and sediments (Yates *et al.* 1996). The findings can be summarised as follows:

Shelduck: There was a country-wide association of high Shelduck densities with estuaries that have large expanses of mud, and a high proportion of mud that had low levels of tidal and wave activity.

Oystercatcher: Higher countrywide densities were associated with less muddy, short and/or wide estuaries with a high degree of wave action and exposure to swell.

Ringed Plover: Densities were higher on the less sandy east and south coast estuaries than on the more sandy west coast estuaries.

Grey Plover: Highest densities were found in the south-east of England, particularly on estuaries with a high proportion of muddy sand and non-sediment, rather than estuaries which were primarily mud and sand.

Knot: Highest densities tended to be found on the larger estuaries.

Dunlin: Highest densities occurred on the more muddy estuaries. They appear to favour narrow estuaries with a wide shore, high tidal range and high exposure.

Curlew: Highest densities were associated with long and/or narrow estuaries containing a high proportion of mud.

Redshank: Densities were highest on the more muddy south and east coast estuaries, associated with long and/or narrow estuary morphology, low tidal range and a low degree of exposure to wave action.

Turnstone: Highest densities were found on estuaries with a high proportion of wet mud.

Generally, whole estuary densities of wader species which habitually forage on estuarine sediments were frequently related to sediment cover variables, particularly with the proportion of mud and/or sand - i.e. Oystercatcher, Dunlin, Grey Plover, Curlew, Redshank. Species with few sediment cover associations tended to be those which are not primarily estuarine in habit - i.e. the open coast species such as Ringed Plover and Turnstone.

3.2.3 Multiple Regression Models Relating Whole Estuary Bird Densities and Environmental Variables

Austin *et al.* (1996) used multiple regression to find sets of environmental variables which would provide the best predictions of bird density (Table 3.2.3.1).

The models obtained by this method predict the densities of principally estuarine waders including Oystercatcher, Dunlin, Curlew, Redshank and Knot reliably. However, they were less reliable for Turnstone and Ringed Plover which are mainly species of open, non-estuarine coasts, and Mallard, which often roost during the day and feed away from the estuary at night.

4. DIET

The distribution of waterfowl is closely tied to the abundance of their prey. A detailed knowledge of the diet of waterfowl and their ability to exploit a range of foodstuffs, allows more accurate predictions of habitat usage and colonisation patterns (Table 4.1.1).

Dark-bellied Brent Goose: traditionally favour mudflats in winter, feeding on eel-grass *Zostera*. Later in winter, marine algae *Enteromorpha* and *Ulva* have major significance in the diet (Cramp & Simmons 1977; Percival & Evans 1997). In early spring, they utilise saltmarsh vegetation such as *Salicornia* and *Puccinellia*. Some animals may also be taken, but probably inadvertently. Since the 1970's, many birds have fed on grasslands and winter cereals where they may cause economic damage to crops (Prater 1981). This food source may now be preferred by the birds in late winter.

Shelduck: mainly eat invertebrates, particularly the gastropod snail *Hydrobia* found in the muddy surface layer of estuaries (Cramp & Simmons 1977; Olney 1965). Other invertebrates from the surface layer of mud are also ingested. In areas where *Hydrobia* is scarce, small oligochaete and polychaete worms form a significant part of the diet (Lack 1993). Vegetable material is of much less importance, but algae, grasses and seeds of various plants are known to be taken.

Oystercatcher: predominantly feed on bivalve molluscs on estuaries, in particular cockles *Cardium*, mussels *Mytilus* and Baltic tell in *Macoma balthica* (Cramp & Simmons 1983; Durell *et al.* 1993; Rands & Barkham 1981). The proportion of these prey in the diet depends principally on availability and location (Goss-Custard *et al.* 1977). Many other molluscan species, crustaceans and polychaetes are also taken.

Ringed Plover: mostly feed on the upper shores and sandier parts of an estuary (Cramp & Simmons 1983). They eat many different invertebrates found in the surface layer of sediment and prey on polychaetes such as *Nereis* and *Nomastus* as they come to the surface (Prater 1981; Pienkowski 1983; Perez-Hurtado *et al.* 1997).

Grey Plover: have a preference for the muddier estuaries in Britain (Prater 1981). When feeding, they are often spread out over the higher mudflats, not concentrated at the water's edge (Lack 1993). The diet consists of various burrowing invertebrates, the proportions of which vary with location and availability. Main prey items include the polychaetes *Nereis*, *Nomastus*, *Arenicola* and *Lanice*, the gastropod *Hydrobia*, bivalves, particularly *Macoma* and small crustaceans (Cramp & Simmons 1983; Durell & Kelly 1990; Goss-Custard *et al.* 1977; Pienkowski 1983; Perez-Hurtado *et al.* 1997).

Knot: are usually found on estuaries with extensive areas of sand and fine sediments (Prater 1981), feeding mainly on the area between mean high water neap and just below mid-tide levels where their main prey can be found (Prater 1972). They feed on a variety of abundant, small invertebrates, chiefly the molluscs *Macoma*, *Cardium* and *Hydrobia* (Cramp & Simmons 1983; Goss-Custard *et al.* 1977; Moreira 1994).

Dunlin: feed mainly on extensive muddy areas of estuaries where they are most often found at the water's edge, predating a variety of invertebrates near the surface of the sediment (Prater 1981; Cramp & Simmons 1983; Lack 1993). Proportions of prey in the diet vary, but the main items are *Nereis*, *Nephtys*, *Hydrobia*, *Littorina*, *Rissoa*, *Theodoxus* and *Macoma* (Durell & Kelly 1990; Goss-Custard *et al.* 1977; Worral 1984). In very cold conditions, when polychaetes such as *Nereis* burrow deeper and are less active, *Hydrobia* become a very important prey item.

Curlew: feed on both animal and plant material, but chiefly invertebrates (Cramp & Simmons 1983). Feeding birds are usually well dispersed on extensive muddy areas of estuaries, but also use inland fields (Prater 1981; Lack 1993). The most important dietary constituents are polychaetes *Nereis* and *Cirriformia*, molluscs *Scrobicularia* and *Macoma* and shore crabs *Carcinus* (Goss-Custard & Jones 1976; Goss-Custard *et al.* 1977; Perez-Hurtado *et al.* 1997).

Redshank: prefer to feed on the upper shore and in the muddy creeks and saltmarsh (Prater 1981). Many prey species are taken on estuaries, but the diet mostly consists of crustaceans *Carcinus*, *Corophium* and *Crangon*, molluscs *Macoma* and *Hydrobia* and polychaetes *Nereis* and *Nephtys* (Goss-Custard 1969; Goss-Custard & Jones 1976; Goss-Custard *et al.* 1977; Cramp & Simmons 1983; Perez-Hurtado *et al.* 1997).

Turnstone: favour rocky shores, but they are also found on estuaries. They have a varied diet, but, in Britain, this consists mainly of shrimps *Gammarus* and *Talitrus*, barnacles *Balanus*, winkles *Littorina* and bivalves *Mytilus* and *Macoma* (Harris 1979; Cramp & Simmons 1983; Whitfield 1990; Lack 1993).

5. EFFECTS OF DISTURBANCE ON WATERFOWL

"Factors affecting habitat quality are subtle and depend not only on food availability, but also on disturbance, predation risk and sediment type" (Percival *et al.* 1998). Disturbance effects are most critical to birds at times when food intake needs to be high, this being in late autumn and early winter for waders and wildfowl, when nutrient reserves are being accumulated in preparation for periods of high energy demand (Madsen 1995). Not only are birds' energy requirements higher, but the costs incurred in finding food are higher in winter (Pienkowski *et al.* 1984). Consequently, tolerance of some forms of disturbance, particularly human, may be by necessity greater in winter, when feeding is more important (Smit & Visser 1993a). Escape flight distances for several species are much smaller in mid-winter (Scott 1989, cited in Davidson 1993) than in late summer and autumn (Smit & Visser 1993b) (Table 5.1.1). It should be noted, however, that this tolerance may not itself be without cost. Birds apparently more tolerant to winter disturbances may in fact also be incurring great energetic costs in the form of stress, but the alternative of flight may be even more costly. Species that need to feed for the longest periods to satisfy their daily energy requirements are more likely to be affected and are most likely to be lost from a site if disturbance is persistent (Madsen 1998a). However, some species may be able to offset a degree of disturbance by behavioural means. For instance, Wigeon (*Anas penelope*), a species known to spend a comparatively large amount of time foraging (Mayhew 1988), increase the amount of nocturnal feeding when disturbed during the day (Owen & Thomas 1979). Many wildfowl species will abandon altogether sites prone to disturbance, particularly hunting, in favour of undisturbed areas (Mayhew 1988; Fox & Madsen 1997). Brent Geese will take flight at distances of over 500 m on mudflats where hunting is common, but may be approached to within 150 m on relatively undisturbed mudflats (Fox & Madsen 1997). In general, quarry species are much less tolerant to disturbance and will take flight much more readily (Madsen 1998b) although hunting can also increase flight distances in non-quarry species. For example, Brent Geese could be approached to 210 m in Denmark before shooting disturbance increasing to 370 m after (Smit & Visser 1993b). A similar effect was noted in Pink-footed Geese (*Anser brachyrhyncus)* in Scotland (Holloway 1997). The nature of disturbance has a bearing on its effect, mobile activities, and especially hunting, being more disruptive than static activities (Madsen 1998a) (Table 5.1.1). Smit & Visser (1993b) reported that windsurfing caused the departure of all duck species as well as Brent Geese. Wigeon have been observed 100 m away from stationery punts, 200 m from mobile punts, but no less than 700 m away from windsurfers (Fox & Madsen 1997). Madsen (1998a), however, reported that whilst hunting had a high disturbance influence, recreational activities such as windsurfing, although eliciting the longest escape flights by waterfowl, had no negative impact on numbers and were at low levels in winter.

Roosting is also a major component of daily time budgets of waterfowl, and several studies have linked population declines to disturbance at, or loss of, roosting sites (Burton *et al.* 1996). Waterfowl tend to keep distances between roosting and feeding areas to a minimum, and will roost on feeding areas if free from predators or disturbance (Fox & Madsen 1997; Furness 1973). Feeding ground selection can be influenced by the availability of safe roosting sites, and birds constantly disturbed from potential roosting areas are more likely to abandon such sites even if suitable feeding resources exist (Fox & Madsen 1997; Burton *et al.* 1996).

6. BIRD MOVEMENTS

6.1 Between Roosting and Feeding Areas

Roosting is an important factor in the energy budgets of wintering waterfowl (Burton *et al.* 1996) and the selection of feeding sites is often influenced by the availability of nearby roosting sites (Furness 1973). Waterfowl tend to prefer roosting sites near to their feeding grounds, especially in winter, to minimise energy expenditure (Burton *et al.* 1996; Fox & Madsen 1997). Distances of 2 km have been reported in Western Sandpipers (*Calidris mauri*) with roosts separated by as little as 5 km (Warnock & Takakawa 1996), and Rehfisch *et al.* (1996) suggest distances of 2-3 km between feeding and roosting sites for several species. Grey Plover, Turnstone, Oystercatcher and Redshank rarely moved far to roost on the Firth of Forth, and Oystercatcher tend to roost at sites closely adjoining the mussel beds on which they feed (Symonds *et al.* 1984). Waterfowl will abandon safe feeding sites if no undisturbed roosting area is closely available (Fox & Madsen 1997).

6.2 Colonisation of New Habitats

The movements of waterfowl between wintering areas varies greatly between species (Pienkowski & Evans 1984; Myers 1986; Ruiz *et al.* 1987). Dark-bellied Brent Geese are extremely faithful to winter and spring feeding and staging sites between years (Ganter & Ebbinge 1997), as are Western Sandpipers, moving very little between widely separated foraging and roosting areas within winters. Likewise, Grey Plover, Turnstone, Oystercatcher and Redshank tend to occupy the same area of the Firth of Forth throughout a winter (Symonds *et al.* 1984). Sanderling (*Calidris alba*), however, exhibit some plasticity in this regard, most remaining within 5 km of the centre of their home-range for up to 95% of the time in California, although some could be found over 25 km away (Myers 1986). Bar-tailed Godwit, Dunlin and Knot tend to range more widely, Knot moving most frequently and often not confined to within an estuary (Symonds *et al.* 1984) within a winter, although both Dunlin and Curlew are known to return to the same stretch of coastline each year. Birds may be more likely to utilise alternative or new areas in response to prey depletion, e.g. Dunlin (Ruiz *et al.* 1989) and Curlew (Townshend 1981, cited in Ruiz *et al.* 1989). Species that move regularly to exploit various food resources, such as Sanderling and Knot, may be less affected by habitat loss and better able to utilise new areas than more site faithful, sedentary species, such as Turnstone (Burton & Evans 1997).

Any choice of compensation site will require not only to provide adequate feeding areas, sufficiently removed from disturbance, but also within reach of suitable disturbance free roost sites. Sites should be chosen on the basis of the threshold levels for roost site distance and degree of disturbance tolerance of the least tolerant, most sedentary species (Rodgers & Smith 1995; Fox & Madsen 1997). Analysis of the roosting patterns of the three least mobile wader species on the Wash, Grey Plover, Dunlin and Redshank (Rehfisch *et al.* 1996), suggested that refuges for roosting birds would need to be located approximately 7, 10 and 9.5 km apart respectively for 50% of the population to be within reach of a refuge during normal roost movements. For 90% of the population to be within reach of a refuge, figures of 2, 2.5 and 3.5 km are given. In the absence of existing roost sites close to a compensation site capable of supporting additional birds, it would be necessary to include such areas within the compensation site itself. If no such natural roosting sites are available, birds will use artificial, man-made roosting sites (Burton *et al.* 1996). Furthermore, inclusion of 'buffer zones' around feeding and roosting sites has been shown to be effective in reducing disturbance to birds (Fox & Madsen 1997). The size and shape of such refuges should be governed by the tolerance of the least tolerant species (Rodgers & Smith 1995).

7. SPATIAL AND TEMPORAL DISTRIBUTION OF WATERFOWL

7.1 Spatial Distribution of Waterfowl Within Estuaries

The distributions of waterfowl within four south-east England estuaries have been obtained from WeBS Low Tide Counts in 1996/97 (Figure 7.1.i to 7.1.xxii). Bird distributions within estuaries are dependent upon species and upon estuary shape. Dark-bellied Brent Geese tend to be found anywhere within an estuary where suitable feeding conditions are found. Shelduck are found in more sheltered areas. On open estuaries, therefore, their distribution tends to be confined to the more narrow side creeks in the upper reaches, whilst they are more widespread on narrow estuaries. Oystercatcher distribution is more variable, and they occur wherever conditions are suitable for prey species, especially mussels. This tends to be in more exposed areas and is illustrated well by their distribution around the mouths of Pagham Harbour and the Stour estuary. Redshank, Curlew, Dunlin, and Knot, as expected from their habitat associations detailed in Table 3.2.2, are found in the middle to upper reaches of estuaries, in more sheltered creeks and bays. This distribution is, however, extended seaward in narrower estuaries. Ringed and Grey Plover are also restricted to these sheltered areas on most south-east estuaries, whilst the more coastal Turnstone is much more frequent in the lower, more exposed reaches and mouths of estuaries. These distributions are a reflection of the strong influence that sediment type, and therefore estuary shape, have on intertidal invertebrates and the waterbirds that prey on them.

7.2 Distribution of Waterfowl Through the Tidal Cycle

The temporal distribution and behaviour of waterfowl on intertidal feeding areas have been examined on several British estuaries, to gain a better understanding of the way birds use this habitat in winter (Clark *et al.* 1990; Evans *et al.* 1997; Armitage *et al.* 1997; Burton *et al.* 1997). In general, the numbers of waterfowl present on intertidal mudflats reaches a peak at around low water, being lowest closer to high water, when little feeding area is exposed and the birds move away to roosts (Figure 7.2.1). The percentage of these birds feeding very quickly approaches 100% soon after feeding areas are exposed as the tide falls. The feeding percentage remains high until the incoming tide again inundates the mudflats and the birds can no longer feed. This indicates the importance of intertidal feeding grounds to these birds, in that they spend a large proportion of the available time utilising these areas.

8. REVIEW OF POTENTIAL COMPENSATION SITE IN RELATION TO WATERFOWL HABITAT REQUIREMENTS AND NUMBERS

8.1 Summary of Habitat Requirements of Wintering Waterfowl

The previous sections have described the various dietary, physical and other factors which affect the distribution of the waterfowl species displaced from Fagbury Flats and Lappel Bank. In providing compensation for the habitats lost to these birds, it is necessary to provide a measure of the relative importance of the areas lost to these waterfowl populations. The relative importance of the numbers of each species on each site have been estimated in relation to the British populations (Table 8.1.1). Of the species prevalent on Lappel Bank, the most important species in terms of national populations were Curlew, Dunlin, Redshank and Shelduck, all species which favour muddy substrata and sheltered shorelines. Similarly, the most important species displaced from Fagbury Flats were Dunlin, Dark-bellied Brent Geese, Grey Plover and Ringed Plover. With the exception of Dunlin, these species tend to favour a mixed environment of saltmarsh and sandy mud.

Thus the compensation site(s) should ideally provide sufficient suitable habitat to support equivalent numbers primarily of Curlew, Dunlin, Dark-bellied Brent Geese, Redshank, Shelduck, Grey Plover and Ringed Plover. The major groups of species displaced from the two sites differ from each other (with the exception of Dunlin) and this probably reflects slight differences in the sediments and aspects between them. Lappel Bank birds were primarily those preferring sheltered, high mud sediments and their associated invertebrate fauna, whilst Fagbury Flats birds were more typical of a slightly more exposed, coastal site, with a mixture of substrata, including an upper shore bounded by saltmarsh.

In Section 8.2, predictions are made of the number of birds colonising each site. These are based on the mean densities of birds observed on six south-east estuaries (Table 3.2.1.1) from Holloway *et al.* (1996) and the latest predictions from ABP Research of areas of saltmarsh and mudflat likely to develop at each site. These same mean densities are used to calculate a predicted number of birds displaced from Lappel Bank and Fagbury Flats (Tables 8.1.2 and 8.1.3). At both sites, the predicted numbers tend to be considerably lower than the numbers known to have been present before port developments. When the peak densities for each species in south-east estuaries are used to predict the total number of waterfowl that could be found on Lappel Bank the estimates are quite similar (1709 *cf* 4946) and the total number of waterfowl found on the Fagbury Flats at high tide are even more similar (3563 *cf* 5099). Lappel Bank was an exceptionally good site with exceptionally high feeding densities of waterfowl. The extremely high densities of waterfowl found at Fagbury are as a result of the presence of Dunlin and Brent Goose roosts, but not as a direct consequence of the importance of the immediate area to feeding birds. This is confirmed by the 1988/89 Fagbury Flats low tide counts which record many fewer birds than the equivalent high tide counts (Table 8.1.3).

Compensation for the lost habitat would ideally comprise a relatively coastal or mid-estuary site, that is neither completely enclosed nor exposed to high levels of coastal wave energy. The site(s) would include sheltered areas, promoting the silting-up required by Curlew, Redshank, Shelduck and Dunlin and the growth of saltmarsh and *Zostera* beds favoured by Dark-bellied Brent Geese, and more exposed, slightly sandier areas favoured by Grey Plover and Ringed Plover. The provision of such site(s) would not only favour these species, but also colonisation by the relatively less important species also displaced: Oystercatcher and Turnstone.

8.2 Site Reviews

The following recommendations and comments are made on the basis of the BTO's bird distribution data and sedimentological and biological data supplied by ABP Research. Some data sets remain incomplete at the time of writing (notably those concerned with intertidal vegetation and benthos), and firmer statements are not possible without further local surveys of biological and physical environmental factors and most importantly without running the full BTO models for all of the candidate sites. These would allow confirmation of initial recommendations and further separation of the most favourable options.

Site 1. St. Mary's Marsh - Outer Thames Estuary (Table 8.2.1.i & ii, Figure 8.2.1). The size of this site is much larger than the area lost to port development, but the exposed position is likely to lead to the settlement of sandier sediments, which hold a relatively poor invertebrate fauna supporting lower densities of birds. A large area of saltmarsh (91 ha) could develop, favouring Dark-bellied Brent Geese. The long section of bund that is to be left could provide concealment for predators such as Sparrowhawks *Accipter nisus*. Disturbance of this type would lower the densities on the site as waterfowl would avoid large areas either side of the bund. The number of waterfowl likely to utilise the site, predicted from mean south-east estuary densities, is short of the target, though the target could be attained if St Mary's were to be managed in such a way as to attain near peak densities of most species. Without extensive modelling, one of the three preferred sites, being expected to hold one third of the number of waterfowl to be compensated for, based simply on extrapolation of mean densities held by south-east estuaries (Table 8.2.10).

Site 2. Blacketts Marsh - Swale Estuary (Tables 8.2.2.i & ii, Figure 8.2.1). On its own, the site is probably not large enough to support sufficient bird numbers. In conjunction with another site, such as Shotley Marshes, a larger area of good habitat may be developed. The number of waterfowl likely to utilise the site, predicted from mean south-east estuary densities, is short of the target, but mudflats adjacent to the site harbour large numbers of feeding birds in winter. If the site develops similarly very high densities, sufficient bird numbers may be compensated for. It is in close proximity to islands in the upper Swale, which form important roosting sites, and the area is relatively undisturbed. However, Blacketts Marsh has some drawbacks. It is already an area of very good grazing marsh and is part of the Swale SPA/Ramsar site.

Site 3. Feldy Marsh - Blackwater Estuary (Tables 8.2.3.i & ii, Figure 8.2.1). The low lying nature and the adjacent mudflats suggest this site could provide good waterfowl feeding habitat, but the projected waterfowl estimate based on mean south-east estuary densities is not high enough to reach the target figure. The high sea-defences around this site may be beneficial as a disturbance barrier between feeding/roosting birds and the open estuary, although in some parts of the site these might also afford some concealment to avian predators. The local benthos appears suitable, at least in composition (although details of biomass are needed), and this site, though probably not ideal, could provide partial compensation in conjunction with other site(s).

Site 4. Weymarks Marsh - Blackwater Estuary (Table 8.2.4.i & ii, Figure 8.2.1). Two options are proposed for development of this site. Option 1 provides a larger area of both saltmarsh and mudflats. The smaller inlets would produce high mud sedimentation which could be favourable to waterfowl. Maintenance may be required to prevent the build up of too much mud leading to excessive saltmarsh development. Numbers predicted from the mean south-east estuary densities are lower than the target numbers. However, given the size of the site and the potential build up of favourable sediments, some species may occur at higher than average densities. The long section of sea wall left standing in both options is a possible drawback, as it may provide cover for raptors and will detract species that prefer wide open spaces. Without extensive modelling, Option 1 is one of the three preferred sites, being expected to hold one third of the number of waterfowl to be compensated for, based simply on extrapolation of mean densities held by south-east estuaries (Table 8.2.10).

Site 5. Nipsells - Blackwater Estuary (Tables 8.2.5.i & ii, Figure 8.2.1). This small, sheltered site is surrounded by mud and saltmarsh. It is situated close to known feeding and roosting areas of most target species. However, it would only be suitable as part of a much larger compensation package as much of the land is high and so likely development by inundation, if any, will probably yield mainly saltmarsh which holds only low densities of waterfowl.

Site 6. St Lawrence Marshes - Blackwater Estuary (Tables 8.2.6.i & ii, Figure 8.2.1). Should this site be developed it would probably be dominated by saltmarsh. It is also of small area and would therefore probably not compensate for the target numbers. However, saltmarsh is an important habitat for some species, such as Brent Geese and Redshank, and thus this marsh could provide partial compensation.

Site 7. Boyton Marshes - Ore Estuary (Table 8.2.7.i & ii, Figure 8.2.1). This large site is in a good sheltered situation, relatively free from disturbance. If muddy sediments with a high density, diverse infauna are deposited, the predicted areas of saltmarsh and mudflats would hold good numbers of wintering waterfowl. If some waterfowl used the area at a higher than average density, this site could provide sufficient compensation for Fagbury Flats and Lappel Bank by itself. The main problem with the site is that it is low lying nature which may promote a high level of inundation and reduce the amount of time that waterfowl can have feeding access to the substrate. Without extensive modelling, this is the most preferred of the three best sites, being expected to hold one third of the number of waterfowl to be compensated for based simply on extrapolation of mean densities held by south-east estuaries (Table 8.2.10).

Site 8. Trimley Marsh - Orwell Estuary (Table 8.2.8.i & ii, Figure 8.2.1). The remaining available area for compensation on this site is small and enclosed, and although adjacent areas currently hold suitable substrata, these are being eroded and replaced with gravel. Even if this were not to become the fate of Trimley Marsh, due to its small size, it would not provide adequate habitat for the target numbers. This small disturbed site is not ideal.

Site 9. Shotley Marshes - Orwell Estuary (Table 8.2.9.i & ii, Figure 8.2.1). This site has promising adjacent intertidal areas of mud with sandy patches, saltmarsh and mudflats with well developed *Enteromorpha* growth. However, the predicted area of mudflat falls short of the target required. Hence, the number of birds predicted from mean south-east estuary and low-tide count (WeBS 1996/97) densities is lower than that to be compensated for. With very good management, it could be used as partial compensation in conjunction with another site (such as Blacketts Marsh). The site may suffer as a result of disturbance. It is narrow and may therefore bring feeding/roosting birds close to footpaths. Also, patchy saltmarsh may develop, providing ideal cover for hunting raptors. The Shotley Marshes are already part of an SPA.

8.3 Summary of Site Recommendations

For each site, the number of birds predicted from the mean south-east estuary densities is lower than the target number of birds to be compensated for. This is partly because the estimate of the number of birds to be compensated for at Fagbury Flats is based on high tide roost counts. Roost counts can exaggerate the importance of an area to feeding waterfowl (Sections 2.1 & 2.2). The particularly high Dunlin numbers comprised not only birds that fed on the Flats, but also birds that fed elsewhere as indicated by the much lower mean 1988/89 winter low tide count (NRA 1993). However, even at low tide, the Fagbury Flats still supported higher feeding densities of waterfowl than do most south-east England estuaries. Lappel Bank also supported very high feeding densities of waterfowl, especially Dunlin. It is therefore recommended that at least these three large sites are investigated in greater depth by more precise modelling to help ensure that the final site(s) selected provides adequate compensation.

St Mary's Marsh, Weymarks Marsh (Option 1) and Boyton Marsh are the three largest sites. These three sites would be expected to hold one third of the number of birds displaced from Fagbury Flats and Lappel Banks based on mean south-east estuary densities (Table 8.2.10). Good management might be expected to attain higher densities of waterfowl, but it is most unlikely that the waterfowl numbers estimated from the peak south-east estuary densities could be attained. St Mary's Marsh may be the least suitable of the three as the nature of its location may promote unfavourable sediment deposition.

Blacketts Marsh and Shotley Marsh appear to be suitable, being close to areas with high numbers and densities of birds and favoured sediments, but are too small on their own, and are better considered as partial compensation areas. The remaining sites appear much less favourable, but in the light of the fragmentary nature of some environmental data available (vegetation and benthos of local intertidal areas) cannot be categorically discounted. It is recommended that the most favourable sites be subjected to detailed local surveys of sediment, vegetation and benthos of adjacent intertidal areas. These analyses can then be used in conjunction with sediment process modelling and waterfowl density modelling using precise estuary morphology parameters to provide reliable predictions of bird usage of these sites post-habitat creation.

Whilst some of the larger sites, particularly Boyton and Weymarks (Option 1), with excellent management may provide compensation for the displaced waterfowl communities of both Lappel Bank and Fagbury Flats, the other promising sites are less likely to do so alone. However, a combination of two or more sites may meet the requirements and has the benefit of spreading the risk of a lower than expected colonisation or an unfavourable sediment settlement. This, however, may be a sub-optimal strategy, because small sites may be intrinsically more susceptible to human and raptorial disturbance. Given this, it is likely that one large compensation site would be better than a combination of smaller sites, all other factors being equal.

It is strongly recommended that extensive detailed modelling is carried out to ensure that the most suitable of the short-listed candidates is selected and that the most suitable management options is selected. It is also recommended that consideration is given to the future monitoring of the selected site(s) to ensure that the value of the compensatory site(s) is adequately judged in this benchmark case.

These recommendations, notwithstanding further more detailed analyses and the development of suitable habitats on selected site(s), are based on present environmental conditions and may be subject to forseen and unforseen environmental change. Sea-level rise as a result of global climate change, and changes to organic inputs and pollutant loads as a result of the Urban Wastewater Treatment Directive may affect the attractiveness of the estuaries concerned and may affect the number of birds that actually colonise the compensatory sites. To maximise colonisation rate, the construction or removal of sea-defences entailed in the creation of new habitats on the chosen site(s) should be timed to minimise disturbance to winter feeding and roosting birds. This will logically therefore be outwith the winter months, but the presence of nearby breeding birds should also be taken into account when planning any work in the spring and early summer. Following the selection and initial alteration of appropriate site(s), a programme of long term monitoring of the sediment processes and floral and faunal colonisation should be set in train, to ensure the sites(s) develop as foreseen and provide the compensation for which they are being managed.

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Species		Two-letter Species Code
Cormorant	*Phalacrocorax carbo*	CA
Dark-bellied Brent Goose	*Branta bernicla bernicla*	DB
Shelduck	*Tadorna tadorna*	SU
Mallard	*Anas platyrhynchos*	MA
Oystercatcher	*Haematopus ostralegus*	OC
Ringed Plover	*Charadrius hiaticula*	RP
Grey Plover	*Pluvialis squatarola*	GV
Lapwing	*Vanellus vanellus*	L.
Knot	*Calidris canutus*	KN
Sanderling	*Calidris alba*	SS
Dunlin	*Calidris alpina*	DN
Curlew	*Numenius arquata*	CU
Redshank	*Tringa totanus*	RK
Turnstone	*Arenaria interpres*	TT

Table 2.1.1 The 14 species of waterfowl considered in this report.

Species	Lappel Bank 1987/88 - 1991/92[a]	Density ha $^{-1}$	Medway estuary[b] 1987/88-1991/92	Density ha $^{-1}$ †	Medway Estuary[c] 1996/97	Density ha $^{-1}$	Medway estuary[d] 1992/93-1996/97	Density ha $^{-1}$ †
CA	2	0.09	504	0.14	*	*	184	0.05
DB	3	0.14	3697	1.03	1226	0.34	3461	0.96
SU	108	4.91	5059	1.41	3627	1.01	5082	1.41
MA	5	0.23	1202	0.33	397	0.11	142	0.40
OC	70	3.18	3339	0.93	1708	0.47	3629	1.01
RP	15	0.68	750	0.21	430	0.12	814	0.23
GV	6	0.27	4808	1.34	1583	0.44	2841	0.79
KN	*	0.00	2615	0.73	1710	0.48	477	0.13
DN	1012	46.00	27873	7.74	21151	5.88	26878	7.47
CU	288	13.09	1945	0.54	650	0.18	1715	0.48
RK	192	8.73	4639	1.29	2149	0.6	2936	0.82
TT	8	0.36	633	0.18	35	0.01	552	0.15

Table 2.1.2 Lappel Bank and whole Medway Estuary bird numbers and densities before and after loss of the Lappel Bank site. (Sources a: RSPB five-year peak mean Low Tide winter counts; b: BoEE High Tide peak mean winter count; c: WeBS Low Tide peak mean winter count; d: WeBS High Tide five-year peak mean winter count).

† It should be noted that these densities are probably over-estimations as roosts may include birds from outside the Bank/estuary.

* Data not available

	Medway	Orwell	Stour	Swale	Blackwater
CA	GB		GB	GB	GB
DB	I	GB	GB	GB	I
SU	I	GB	GB	GB	I
MA					
OC	GB			GB	
RP	I	GB	I		
GV	I		I	I	I
L.					
KN			I	I	
SS					
DN	I	GB	I	GB	I
CU					GB
RK	I	I	I	GB	I

Table 2.1.3 The relative importance of wintering populations of some waterbird species on five south-east estuaries (from Waters *et al.* In prep.). (GB = nationally important, I = internationally important).

Species	Fagbury Flats 1988/89[a]	Density ha^{-1}	Fagbury Flats 1990/91-1994/95[b]	Density ha^{-1} †	Orwell Estuary 1996/97[c]	Density ha^{-1}	Orwell Estuary 1992/93-1996/97[d]	Density ha^{-1} †
CA	3	0.09	5	0.16	38	0.04	*	*
DB	80	2.50	346	10.81	571	0.67	1393	1.64
SU	3	0.09	19	0.59	722	0.85	2309	2.72
MA	4	0.13	0	0.00	527	0.62	*	*
OC	23	0.72	105	3.28	745	0.88	972	1.14
RP	9	0.28	54	1.69	133	0.16	407	0.48
GV	34	1.06	127	3.97	136	0.16	335	0.39
L.	467	14.59	175	5.47	1109	1.30	1891	2.22
KN	9	0.28	24	0.75	705	0.83	836	0.98
SS	9	0.28	4	0.13	0	0	3	0.00
DN	325	10.16	2610	81.56	6575	7.74	9835	11.58
CU	1	0.03	1	0.03	567	0.67	750	0.88
RK	100	3.13	43	1.34	2007	2.36	1744	2.05
TT	22	0.69	50	1.56	50	0.06	250	0.29

Table 2.2.1 Fagbury Flats and whole Orwell Estuary bird numbers and densities before and after loss of the Fagbury Flats site. (Sources: a: NRA mean winter low tide count 1988/89; b: WeBS five- year peak mean High Tide winter count for 1990/91-1994/95; c: WeBS Low Tide peak mean winter count for 1996/97) d: WeBS five- year peak mean High Tide winter counts for 1992/93-1996/97).

† It should be noted that these densities are probably over-estimations as roosts may include birds from outside the Flats/estuary.

* Data not available

Prey Species		Sediment Characteristics	Predator Species
Cardium edule	large	Low clay sediments, low organic content.	OC KN
	small	High fine sand sediments	
Macoma balthica		High silt sediments, low organic content.	OC, RP, KN, RK, TT
Hydrobia ulvae		High silt sediments, low organic content.	SU, RP, GV, DN, RK
Mytilus edulis		High organic content.	OC, TT
Nereis diversicolor		High clay and silt sediments, high organic content.	OC, CU, RK

Table 3.1.1 Major sediment type correlates of density for some invertebrates that are preyed upon by waders (Yates *et al.* 1993).

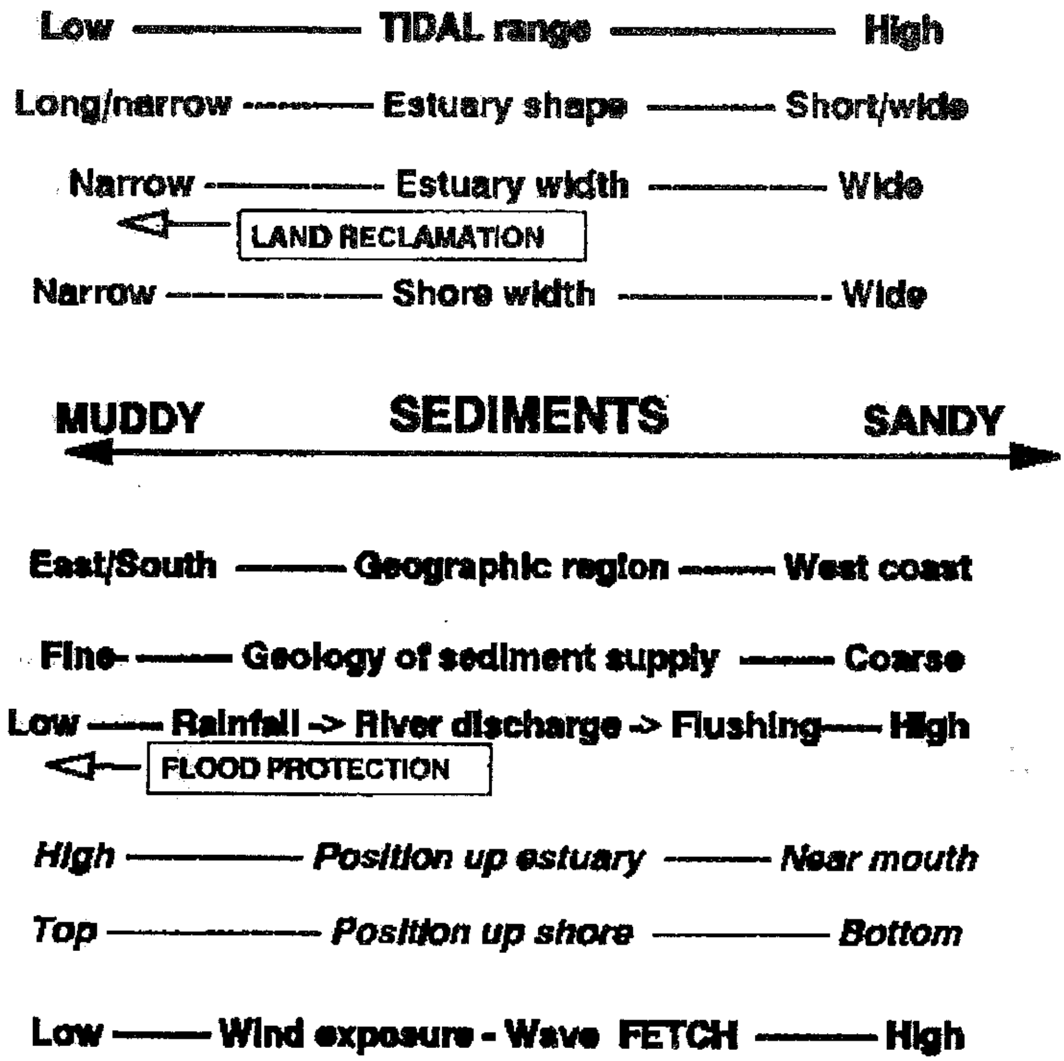


Table 3.1.2 Variation of sediment characteristics with estuary morphology factors (Yates *et al.* 1996).

Species	Sediment	Vegetation	Topography	Exposure
DB		*Zostera* beds [5] Salt marsh [3]		
SU	High mud area, Muddy sediment [4]		Low tidal range[4] Narrow Estuary [4]	Low fetch [4]
MA	Mud/sand sediment [4]	Low saltmarsh area [4]		Low swell [4]
OC	Mud/sand sediment [4] Fine sand, low silt sediment [6] High sand area [7]	Saltmarsh [4]	Wide estuary [4] Wide shore [7]	High swell [4] High fetch [4]
RP	Muddy sediment [1] Sandy areas [9]		Low tidal range [4]	Low swell [4]
GV	Mud/sand sediment [4] Low silt sediment [6] High mud area [7] Muddy sediment [8]		Wide shore [7]	
KN	High mud area [4,7] Low fine sand, high silt sediment [6,8]	Saltmarsh [4]	Wide channels [4]	
DN	Muddy sediment [2, 4,8] Little sand [1] Low coarse sand and high silt sediment [6] High mud area [7]		Narrow shore [1,4] High tidal range [4] Narrow estuary [4]	Low swell [4] Low fetch [4]
CU	Muddy sediment [4,8] Little sand [1] Low fine sand sediment [6] High mud area [7] Inland fields [8]		Narrow estuary [4]	
RK	Muddy sediment with little sand [1,8] Low coarse sand, high clay sediment [6] High mud area [7]	Saltmarsh [8]	Low tidal range [4] Narrow estuary [4] Wide shore [7]	

TT	Muddy sediment [4] Rocky shores [9]

Table 3.1.3 Summary of habitat preferences of waterfowl on British estuaries (Sources: [1]Rehfisch *et al* 1997; [2]McCulloch & Clark 1991; [3]Garter & Ebbinge 1997; [4]Austin *et al.* 1996; [5]Percival & Evans 1997; [6]Yates *et al* 1993; [7]Yates & Goss-Custard 1991; [8]Prater 1981; [9]Cramp & Simmons 1983).

Species	Mud (136)	Other (17)	Saltmarsh (37)	Mixed (21)	Sand (32)	Mud/Sand (4)
SU	1.116 7.419	0.022 0.348	0.137 1.445	0.386 2.251	0.161 3.782	0.256 1.241
MA	0.051 3.077	0.008 0.136	0.026 0.441	0.113 1.076	0.075 1.585	0.015 0.153
OC	0.347 5.777	2.098 7.653	0.016 0.655	0.911 5.038	2.003 36.694	2.297 6.041
RP	0.119 4.707	0.112 0.545	0.005 0.364	0.119 1.986	0.150 2.527	0.020 0.116
GV	0.474 6.683	0.685 5.685	0.047 0.867	0.880 25.101	0.963 15.117	0.170 0.557
L.	0.796 27.176	0.000 0.000	0.061 1.795	1.892 7.952	0.024 1.529	0.001 0.011
KN	0.418 35.460	4.118 19.009	0.000 0.000	0.913 17.613	2.355 23.345	2.563 14.864
SS	0.004 0.838	0.001 0.034	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000
DN	9.208 88.055	10.044 51.542	0.107 3.152	2.293 14.804	3.830 49.424	1.902 7.317
CU	0.488 9.221	0.802 2.950	0.075 0.609	0.292 2.088	0.159 1.020	0.143 0.495
RK	2.309 25.697	0.562 4.119	0.293 2.741	1.050 13.436	0.324 3.422	0.214 0.589
TT	0.048 3.743	0.498 6.809	0.033 2.153	0.583 11.620	0.176 1.929	0.125 0.305

Sediment Types (n)

Table 3.2.1.1 Mean and peak densities (ha^{-1}) of waterfowl observed in count units of differing substratum type on six south-east estuaries (data from Holloway *et al.* 1996).

Estuary	Area	Density ha^{-1}	Bird Numbers
Medway 96/97	3600	0.341	1226
Pagham Harbour 96/97	389	2.018	785
Orwell 96/97	847	0.674	571
Stour 96/97	1597	0.644	1029
Beaulieu 96/97	569	0.951	541
Chichester Harbour 96/97	2460	2.035	5007
Crouch/Roach 95/96	1048	1.737	1820
Southampton Water 95/96	1521	0.977	1486
Pagham Harbour 95/96	389	7.632	2969
TOTAL	12420	1.243	15434

Table 3.2.1.2 Mean densities of Brent Geese on estuaries calculated from WeBS Low Tide Counts.

Variable name	Units	Definition
EAREA	ha	Total area of estuary from mouth to defined upper limit, including channel.
ELENGTH	km	Distance up mid-channel from mouth to upper limit.
EWMAX	km	Maximum of the total width of the estuary measured at ten or more representative transects across the estuary.
EWMEAN	km	Mean of the total width of the estuary measured at ten or more representative transects across the estuary.
ESHAPE1		Estuary shape variable. Highest values denote relatively long and narrow estuaries. = ELENGTH / EWMAX
ESHAPE2		Estuary shape variable. Highest values denote relatively long and narrow estuaries. = ELENGTH / EWMEAN
ETRANGE	m^{-1}	Mean spring tidal range (M.S.H.W. - M.S.L.W.)
EWSHORE	km	Mean shore (intertidal) width averaged over ten equally spaced transects on each side of the estuary, measured from low water to upper limit of saltmarsh or sea wall.
EWCHANN	km	Mean low water channel width from ten transects.
EWMOUTH	km	Estuary mouth width.
ESWELL		Estuary exposure to swell from the sea. = EWMOUTH / EWMAX
EDEPTH1		Estuary depth index; estuaries with relatively wide channels will tend to be deeper. = EWCHANN / EWMEAN
ESHAPE1T	m^{-1}	Derived variable =ELENGTH/(EWMAX x ETRANGE)
EFETCH2	km	Median value of WFETCH2
EFETCH10	km	EFETCH2 truncated to have a maximum value of 10 km.
ELAT	°	Latitude.
ELONG	°	Longitude.

Table 3.2.2.1 Definitions of the whole estuary morphological variables. (From Austin *et al.* 1996).

Variable name	Units	Definition
ETWETMUD	ha	Total area of count polygons within an estuary that is wet mud subclass =Σ(TWETMUD).
ETWETSAN	ha	Total area of count polygons within an estuary that is wet mud subclass =Σ(TWETSAND).
E2PMUD	%	Proportion of the total sediment area within an estuary that is mud = E2TMUD / E2TAREASM
E2PSAND	%	Proportion of the total sediment area within an estuary that is sand = E2TSAND / E2TAREASM
E2PMUDSAN	%	Proportion of the total sediment area within an estuary that is muddy sand = E2TMUDSAND / E2TAREASM
E2PAREASM	%	Proportion of the total area within an estuary that is sediment = E2TAREASM / E2TAREA
E2POTHER	%	Proportion of the total area within an estuary that is not sediment = E2TOTHER / E2TAREA
EPWETMUD	%	Proportion of the total sediment area within an estuary that is wet mud = EWETMUD / E2TAREASM
EPWETSAN	%	Proportion of the total sediment area that is wet sand = EWETSAND / E2TAREASM
ETMUD	ha	Total area of all mud subclasses
ETMUDSAN	ha	Total area of all muddy sand subclasses
ETSAND	ha	Total area of all sand subclasses
ETOTHER	ha	Total area of all subclasses excluding TMUD, TMUDSAND and TSAND
ETAREASM	ha	Total sediment area = TMUD + TMUDSAND + TSAND
ETAREA	ha	TAREASM + TOTHER
PMUD	%	% of total sediment area which is mud = 100 TMUD/TAREASM
PMUDSAND	%	% of total sediment area which is muddy-sand = 100 TMUDSAND/TAREASM
PSAND	%	% of total sediment area which is sand = 100 TSAND/TAREASM

Table 3.2.2.2 Definitions of the derived sediment cover class variables. All areas are in hectares. (From Austin *et al.* 1996).

		E2PMUD (arcsine) %	E2PSAND (arcsine) %	E2PMUDSAN (arcsine) %	E2PAREASM (arcsine) %	E2POTHER (arcsine) %	EPWETMUD (arcsine) %	EPWETSAND (arcsine) %	ETAREA *ha*	ETMUD *ha*	ETSAND *ha*	ETMUDSAN *ha*	ETAREASM *ha*	ETOTHER *ha*	ETWETMUD *ha*	ETWETSAND *ha*
Shelduck	CW	0.394*	-0.533**					-0.429*		0.513**						
	E&S															
	W															
Mallard	CW		-0.387*													
	E&S															
	W			0.685**	-0.886***	0.838***										
Oystercatcher	CW	-0.388*			0.488**	-0.473*		0.467*			0.430*	0.397*	0.438*			0.447*
	E&S	-0.257*			0.534*							0.802***				
	W					-0.573*										
Ringed Plover	CW	0.388*	-0.482*					-0.465*			-0.358*					
	E&S															
	W															
Grey Plover	CW			0.478*												
	E&S			0.709**												
	W															
Lapwing	CW	0.470*	-0.431*				0.450*									
	E&S															
	W	0.952***	-0.777**				0.821***									
Knot	CW									0.690***					0.687***	
	E&S							0.602*	0.747**	0.836***		0.612*	0.654**	0.871***	0.857***	
	W															
Sanderling	CW															
	E&S															
	W															
Dunlin	CW	0.624***	-0.604***													
	E&S															
	W	0.781**						-0.430*		0.471*						
Curlew	CW	0.496**	-0.483*				0.702***	-0.382*								
	E&S						0.613*									
	W						0.616*									
Redshank	CW	0.712***	-0.677***				0.518**	-0.548**								
	E&S	0.580*	-0.562*													
	W															
Turnstone	CW						0.390*									
	E&S															
	W															

Table 3.2.2.3 Correlations between sediment cover variables (some arcsine transformed to normalise distribution) and waterfowl densities on 25 British estuaries (CW = countrywide estuaries; E&S = south and east estuaries only; W = west coast estuaries only). (*P < 0.05, **P < 0.01, ***P < 0.001)

		ELAT *	ELONG *	EAREA *ha*	ELENGTH *km*	ETRANGE *m*	EDEPTH1 *	EFETCH2 *km*	EFETCH1 0*km*	EWMAX *km*	EWMEAN *km*	EWSHORE *km*	EWCHANN *km*	ESWELL *km*	EWMOUTH *km*	ESHAPE1 (Log10)	ESHAPE2 (Log10)	ESHAPE1T (Log10)
Shelduck	CW		0.705***			-0.420*			-0.465*									
	E&S		0.600*															
	W																0.567*	
Mallard	CW													-0.471*				
	E&S																	
	W																	
Oystercatcher	CW							0.568**	0.525**	0.410*	0.518**	0.680***		0.508**	0.534**	-0.393*	-0.419*	
	E&S	0.594*					-0.557*											
	W					0.365*		0.649*	0.687**	0.697*	0.760**	0.823***		0.627*	0.766**			-0.649*
Ringed Plover	CW	-0.423*				-0.448*								-0.453*				
	E&S																	
	W	-0.612*	-0.723**											-0.582*				
Grey Plover	CW		0.389*															
	E&S																	
	W																	
Lapwing	CW																	0.416*
	E&S																	
	W								-0.633*							0.614*		
Knot	CW																	
	E&S														0.615*			
	W			0.661*	0.706*					0.736**	0.715**	0.775**	0.626*		0.788**			
Sanderling	CW			0.410*	0.635***		0.406*			0.496*			0.603**		0.402*			
	E&S			0.952***	0.895***		0.600*			0.900***	0.849***		0.940***		0.784**			
	W																	
Dunlin	CW	-0.404*	0.781***			-0.491*			-0.450*			0.410*					0.368*	0.393**
	E&S		0.875***															
	W																	
Curlew	CW															0.418*		0.548*
	E&S																	
	W															0.726**	0.744**	
Redshank	CW		0.858***			-0.592**			-0.470*							0.559**	0.504**	0.751***
	E&S		0.804***			-0.701**												0.646*
	W		0.571*					0.607*										
Turnstone	CW																	
	E&S																	
	W																	

Table 3.2.2.4 Correlations between estuary morphology variables (some log10 transformed to normalise their distributions) and waterfowl densities on 25 British estuaries (CW= countrywide estuaries; E&S = south and east estuaries only; W = west coast estuaries only). (*P<0.05, **P<0.01, ***P<0.001)

Predictive model variables and variance explain by models

Species	Variance	Major Predictors	Area
SU	47.4%	Longitude	CW
MA	20.9%	Swell (-)	E + S
OC	75.2%	Area of muddy sand/Latitude	E + S
RP	23.5%	Proportion of sand/Latitude (-)	CW
GV	53.8%	Proportion of muddy sand/Proportion of mixed habitat	E + S
L.	-	Mean regional density	E + S
KN	59.0%	Area of mud/Fetch	E + S
SS	-	Mean country density	CW
DN	84.3%	Longitude/Latitude/Tidal range	E + S
CU	46.1%	Proportion of wet mud	CW
RK	86.7%	Longitude/Shape/Tidal range	CW

Table 3.2.3.1 Summary of models predicting waterfowl densities on British estuaries (Austin *et al.* 1996). (E&S = south and east estuaries only; CW = countrywide estuaries).

		Brent Goose	Shelduck
Plants	Algae	***ENTEROMORPHA*** ***ULVA*** *Cladophera* Brown and red algae	*Enteromorpha* *Vaucheria*
	Gramineae & Cyperaceae	*Puccinellia* *Festuca* *Spartina* Wheat Barley	Seeds: *Scirpus*
	Other families	***ZOSTERA*** *Salicornia* *Aster* *Triglochin*	Seeds: *Sueda* *Atriplex* *Salicornia*
Invertebrates	Molluscs		***HYDROBIA*** *Cardium* *Macoma* *Mytilus* *Montacula* *Cingula* *Buccinum* *Littorina* *Skenea* *Paludina* *Tellina* *Nucula* *Mya* *Theodoxus*
	Crustaceans		Small crabs Shrimps Prawns Sandhoppers *Artemia* *Corophium*
	Annelids		*Nereis*
	Arthropods		Orthoptera *Carabus nitens* Chironomidae larvae

Table 4.1.1 The diet of waterfowl. Main food items are shown in capital letters. (Sources : Cramp & Simmons, 1977; Cramp & Simmons, 1983; Campbell, J.W. (1946); dit Durell, S.E.A. le V. & Kelly, C.P. (1990); dit Durell, S.E.A.leV., Goss-Custard, J.D. & Caldow, R.W.G. (1993); Goss-Custard, J.D. (1969); Goss-Custard, J.D. & Jones, R.E. (1976); Goss-Custard, J.D., Jones, R.E. & Newbery, P.E. (1977); Harris, P.R. (1979); Moreira, F. (1994); Olney, P.J.S. (1965); Owen, M. (1973); Percival, S.M. & Evans, P.R. (1997); Perez-Hurtado, A., Goss-Custard, J.D. & Garcia, F. (1997); Pienkowski, M.W. (1983); Prater, A.J. (1972); Prater, A.J. (1981); Rands, M.R.W. & Barkham, J.P. (1981); Whitfield, P.D. (1990); Worral, D.H. (1984)).

		Oystercatcher	Ringed Plover	Grey Plover
Plants	Algae			
	Gramineae Cyperaceae			
	Other families			
Invertebrates	Molluscs	***CARDIUM*** ***MYTILUS*** ***MACOMA*** *Littorina* *Nucella lapillus* *Patella* *Tellina* *Scrobicularia* *Mya*	*Macoma* *Hydrobia* *Littorina*	***HYDROBIA*** ***MACOMA*** *Cardium* *Mytilus* *Mya* *Littorina* *Dreissenidae*
	Crustaceans	*Carcinus* *Crangon* Amphipods	*Corophium* *Bathyporeia* *Eurydice* Shrimps	***CARCINUS*** *Upogebia* *Cleistosoma* *Retusa* *Corophium* *Crangon*
	Annelids	*Nereis* *Arenicola*	***NEREIS*** ***NOMASTUS*** *Arenicola* *Scopolos* *Phyllodoce* Small oligochaetes	***NEREIS*** ***NOMASTUS*** ***ARENICOLA*** ***LANICE*** *Phyllodoce*
	Arthropods		Insect adults and larvae	

Table 4.1.1 (Cont.) The diet of waterfowl. Main food items are shown in capital letters.

		Knot	Dunlin	Curlew
Plants	Algae	*Enteromorpha*		*Ulva*
	Gramineae Cyperaceae	Seeds: various	Seeds: *Scirpus*	Various grasses and cereals
	Other families		*Zostera* Seeds: *Ruppia* *Najas*	Mosses *Equisetum* *Rubus* berries
Invertebrates	Molluscs	*MACOMA* *CARDIUM* *HYDROBIA* *Tellina* *Littorina* *Mytilus* *Rissoa* *Zua* *Limosa* *Mya* *Homalogyra* *Retusa* *Paludina*	*HYDROBIA* *LITTORINA* *RISSOA* *THEODOXUS* *MACOMA* *Tellina* *Mytilus* *Retusa* *Cardium* *Scrobicularia*	*SCROBICULARIA* *MACOMA* *Mytilus* *Mya* *Cardium* *Hydrobia*
	Crustaceans	*Carcinus* *Corophium* *Gammarus* *Balanus* *Crangon*	Amphipods *Carcinus* *Crangon* *Mysidacea* *Cladocera* *Artemia salina*	*CARCINUS* *Crangon* *Corophium* *Gammarus* *Bathyporeia* *Orchestia*
	Annelids	*Nereis* Oligochaetes	*NEREIS* *NEPHTYS* *Scolopolos* *Arenicola*	*NEREIS* *CIRRIFORMIA* *LANICE* *Arenicola*
	Arthropods	Insect adults and larvae	Insect adults and larvae	Insects inland
	Other	*Hydrozoa* Small starfish		

Table 4.1.1 (Cont.) The diet of waterfowl. Main food items are shown in capital letters.

		Redshank	Turnstone
Plants	Algae		Various
	Gramineae Cyperaceae		*Carex* *Kobresia*
	Other families		Seeds: *Juncus* *Polygonum* *Pedicularis*
	Other		Mosses
Invertebrates	Molluscs	***MACOMA*** ***HYDROBIA*** *Scrobicularia* *Littorina* *Cardium* *Tellina* *Mytilus*	***LITTORINA*** ***MYTILUS*** ***MACOMA*** *Cardium* *Patella* *Hydrobia* *Theodoxus* *Lymnaea* *Calliostoma* *Lepidochitona*
	Crustaceans	***COROPHIUM*** ***CRANGON*** ***CARCINUS*** *Gammarus*	***GAMMARUS*** ***BALANUS*** ***CARCINUS*** *Eupagurus* *Talitrus* *Hyale*
	Annelids	***NEREIS*** ***NEPHTYS***	*Nereis* *Lumbricillus*
	Arthropods		Insect adults and larvae
	Other		*Ophiuroidea* *Psammechinus miliaris*

Table 4.1.1 (Cont.) The diet of waterfowl. Main food items are shown in capital letters.

Species	Walkers /Fishermen	Windsurfers	Cars	Aircraft	Boats
OC	10-50 m [1] 100-200 m [2] 113 m [2] 60 m [2]	130 m [2]	50-200 m [2]*	200-500m [2]*	50-100m [2]
CU	20-35 m [1] 95 m [2] 300-500 m [2]	400 m [2]			190 m [2]
RK	10-40 m [1] 95 m [2] 200-300 m [2]	280 m [2]			
DN	8-10 m [1] 100-300 m [2]				
SU		380 m [2]			

Table 5.1.1 Escape Flight Distances (EFD) for several species of waterfowl in response to different forms of human disturbance. (Sources: 1. Scott (1989), cited in Davidson (1993) values recorded in mid-winter; 2. Smit & Visser (1993b), values recorded in late summer and autumn. * = approximate means for several species).

Species	Number				National Population	Proportion of National Population	
	(1) Lappel Bank	% Total of number	(2) Fagbury Flats	% Total of number		Lappel Bank	Fagbury Flats
CA	2	0.11	5	0.14	13,000	<0.1	<0.1
DB	3	0.17	346	9.71	100,000	<0.1	0.35
SU	108	6.32	19	0.53	75,000	0.14	<0.1
MA	5	0.26	*	*	500,000	<0.1	<0.1
OC	70	4.1	105	2.95	360,000	<0.1	<0.1
RP	15	0.9	54	1.52	29,000	<0.1	0.19
GV	6	0.4	127	3.56	43,000	<0.1	0.30
L.	0	0	175	4.91	2,000,000	0	<0.1
KN	*	0	24	0.67	290,000	*	<0.1
SS	0	0	4	0.11	23,000	0	<0.1
DN	1012	59.2	2610	73.25	530,000	0.20	0.49
CU	288	16.9	1	0.03	120,000	0.24	<0.1
RK	192	11.2	43	1.21	110,000	0.17	<0.1
TT	8	0.5	50	1.40	64,000	<0.1	<0.1
Total	1709		3563				

Table 8.1.1 Proportion of national populations of waterfowl displaced by the developments on Lappel Bank and Fagbury Flats. Bird numbers supplied by 1) WeBS and 2) RSPB. National populations are based on the most recent estimates: wildfowl follow Kirby (1995) and waders follow Cayford & Waters (1996) - both cited in Cranswick *et al.* (1997). * = Data not available.

Species	Bird numbers			
	Lappel Bank 1987/88-1991/92	Predicted numbers on Lappel Bank		
		Mud	Mud / Sand	Sand
CA	2	n/a	n/a	n/a
DB	3	26 (154)	26 (154)	26 (154)
SU	108	25 (163)	6 (27)	4 (83)
MA	5	1 (68)	0 (3)	2 (35)
OC	70	8 (127)	51 (133)	44 (807)
RP	15	3 (104)	0 (3)	3 (56)
GV	6	10 (147)	4 (12)	21 (333)
L.	0	18 (598)	0 (0)	1 (34)
KN	*	9 (780)	56 (327)	52 (514)
SS	0	0 (18)	0 (0)	0 (0)
DN	1012	203 (1937)	42 (161)	84 (1087)
CU	288	11 (203)	3 (11)	3 (22)
RK	192	51 (565)	5 (13)	7 (76)
TT	8	1 (82)	3 (7)	4 (42)
TOTAL	1709	366 (4946)	196 (851)	251 (3243)

Table 8.1.2 Lappel Bank five-year peak mean winter peak low tide count of birds (RSPB 1987/88-1991/92) and numbers predicted from the same area using densities from Table 3.2.1.1. Peak values are shown in brackets.

Species	Bird numbers				
	Fagbury Flats peak mean high tide count 1990/91-1994/95	Fagbury Flats 1988/89 mean low tide count	Predicted numbers on Fagbury Flats		
			Mud	Mud / Sand	Sand
CA	5		n/a	n/a	n/a
DB	346	80	38 (224)	38 (224)	38 (224)
SU	19	3	24 (166)	7 (42)	5 (93)
MA	0	4	2 (98)	0 (5)	2 (51)
OC	105	23	7 (123)	46 (129)	40 (742)
RP	54	9	2 (99)	0 (7)	3 (55)
GV	127	34	10 (144)	4 (22)	20 (313)
L.	175	467	25 (870)	0 (0)	1 (49)
KN	24	9	8 (709)	51 (297)	47 (467)
SS	4	9	0 (27)	0 (0)	0 (0)
DN	2610	325	185 (1799)	39 (184)	78 (1026)
CU	1	1	11 (192)	4 (17)	4 (28)
RK	43	100	50 (547)	8 (45)	10 (102)
TT	50	22	1 (101)	3 (32)	4 (64)
TOTAL	3563	1086	363 (5099)	200 (1004)	252 (3214)

Table 8.1.3 Fagbury Flats five-year peak mean winter high tide count of birds (WeBS 1990/91-1994/95), mean winter low tide count (NRA 1988/89) and numbers predicted from the same area using densities from Table 3.2.1.1. Peak values are shown in brackets.

[1]**Area**	91 ha saltmarsh, 95 ha mudflat (latest predictions from ABP Research).
Situation	Southern shore of Thames Estuary, near mouth. Thames estuary is of national importance for wintering Shelduck, Dunlin, Dark-bellied Brent Geese, Redshank, Ringed and Grey Plover (Table 2.1.3).
[1]**Tidal Range**	3.15 m (mean spring).
[1]**Exposure**	Long ENE fetch from mouth of estuary.
Nature of Adjacent Intertidal Sediments	The site is fronted by a large foreshore of sandstrip and then mudflats in front of well developed saltmarsh[1].
Nature of Adjacent Intertidal Vegetation	Well developed saltmarsh vegetation and some *Spartina* colonisation of mudflats[1]. Some *Zostera* and *Ruppia* beds on sites up stream[2].
Nature of Adjacent Intertidal Benthos	No data available.
[1]**Disturbance**	Public footpath, agriculture, summer water sports.
Estimate of Bird Numbers Colonising Site	Sandy or muddy sand sediments are unlikely to maintain high densities and therefore high enough numbers of birds (Table 8.2.1.ii)

Table 8.2.1.i Environmental site characteristics for Site 1. St. Mary's Marshes. (Sources: 1: ABP Research 1998; 2: Buck 1997).

Species	Numbers displaced from Lappel Bank and Fagbury Flats	Predicted bird numbers using site		
		Saltmarsh and mud	Saltmarsh and muddy sand	Saltmarsh and sand
CA	7	n/a	n/a	n/a
DB	349	221 (1302)	221 (1302)	221 (1302)
SU	127	118 (836)	37 (249)	28 (491)
MA	5	7 (332)	4 (55)	9 (191)
OC	175	34 (608)	220 (634)	192 (3546)
RP	69	12 (480)	2 (44)	15 (273)
GV	133	49 (714)	20 (132)	96 (1515)
L.	175	81 (2745)	6 (164)	8 (309)
KN	24	40 (3369)	244 (1412)	224 (2218)
SS	4	0 (80)	0 (0)	0 (0)
DN	3622	884 (8652)	190 (982)	374 (4982)
CU	289	53 (931)	20 (102)	22 (152)
RK	235	246 (2691)	47 (305)	57 (576)
TT	58	8 (552)	15 (225)	20 (379)
TOTAL	5272	1753 (23292)	1026 (5606)	1266 (15934)

Table 8.2.1.ii Estimated bird numbers using St Mary's Marshes after development, allowing for 91 ha saltmarsh and 95 ha mudflat (mud, muddy sand and sand). Numbers of Brent Geese estimated using low tide count whole estuary densities (Table 3.2.1.2); numbers of other species estimated using densities in Table 3.2.1.1.

[1]**Area**	27 ha saltmarsh, 43 ha mudflat.
Situation	Upper Swale estuary adjacent to narrow channel. Swale estuary is Internationally important for Grey Plover and Knot, and holds nationally important numbers of Dark-bellied Brent Geese, Shelduck, Oystercatcher, Dunlin and Redshank (Table 2.1.3).
[1]**Tidal Range**	2.65 m (mean spring).
[1]**Exposure**	Sheltered.
Nature of Adjacent Intertidal Sediments	Wide foreshore with creeks. Silting and accretion evident in creeks. Well developed saltmarsh with secondary colonisation.
Nature of Adjacent Intertidal Vegetation	Well developed saltmarsh. *Zostera* beds at Faversham, further seaward[2].
Nature of Adjacent Intertidal Benthos	Oyster beds ~10 Km distant[1]. Mussel beds in upper estuary[2]. No other data available.
Disturbance	Public footpath, RSPB reserve opposite, Land to East and West industrially owned but unused. Marina adjacent in Conyer Creek - windsurfing. Some wildfowling on adjacent marshes.
Estimate of Bird Numbers Colonising Site	Islands in Upper Swale estuary are important winter roosting sites. 1992/93 Low Tide Counts (WeBS) for adjacent mud flats (Figure 8.2.2) show high densities of birds (Table 8.2.2.ii), so high densities may colonise the site. On its own, it is probably not large enough to hold adequate numbers of birds.

Table 8.2.2.i Environmental site characteristics for Site 2. Blacketts Marsh. (Sources: 1: ABP Research 1998; 2: Buck 1997).

Species	Density on adjacent mudflats ha^{-1}	Numbers displaced from Lappel Bank and Fagbury Flats	Predicted bird numbers using site: Saltmarsh and mud	Saltmarsh and muddy sand	Saltmarsh and sand
CA	n/a	7	n/a	n/a	n/a
DB	1.00	349	74 (434)	74 (434)	74 (434)
SU	>5.00	127	51 (346)	14 (81)	10 (190)
MA	0.01-0.25	5	3 (141)	1 (15)	4 (77)
OC	2.00-5.00	175	15 (261)	99 (272)	86 (1590)
RP	0.01-0.25	69	5 (209)	1 (12)	7 (116)
GV	2.00-3.00	133	21 (304)	8 (40)	42 (667)
L.	5.00-30.00	175	35 (1203)	1 (35)	2 (100)
KN	>5.00	24	18 (1525)	110 (639)	101 (1004)
SS	0	4	0 (36)	0 (0)	0 (0)
DN	5.00-30.00	3622	398 (3846)	84 (375)	167 (2185)
CU	0.01-2.00	289	22 (408)	8 (33)	8 (55)
RK	4.00-5.00	235	105 (1157)	15 (77)	19 (200)
TT	0	58	3 (202)	6 (54)	8 (124)
TOTAL		5272	750 (10072)	421 (2067)	528 (6742)

Table 8.2.2.ii Densities of birds on adjacent mudflats (low tide count) and estimated bird numbers using Blacketts Marshes after development, allowing for 27 ha saltmarsh and 43 ha mudflat (mud, muddy sand and sand). Numbers of Brent Geese estimated using low tide count whole estuary densities (Table 3.2.1.2); numbers of other species estimated using densities in Table 3.2.1.1.

[1]Area	82 ha saltmarsh, 42 ha mudflat.
Situation	North bank of lower Blackwater estuary. The Blackwater estuary holds internationally important numbers of wintering Dark-bellied Brent Geese, Shelduck, Grey Plover, Dunlin and Redshank, and is nationally important for wintering Curlew.
[1]Tidal Range	2.4 m (mean spring).
[1]Exposure	Relatively exposed to Easterly fetch.
Nature of Adjacent Intertidal Sediments	The site is currently fronted on all sides by ~50 m of mudflats, with many creeks and saltings, but these are eroding at ~0.2 m per year[1]. The site is historically reclaimed saltmarsh[1].
Nature of Adjacent Intertidal Vegetation	*Enteromorpha* observed growing on fronting mudflats.
Nature of Adjacent Intertidal Benthos	Some data of intertidal benthos for mudflats on the north shore of the estuary - near Feldy Marshes (Table 8.2.11). 14.5% of the invertebrate taxa present are food species for waterfowl. Namely Ringed Plover, Curlew, Dunlin, Redshank, Grey Plover, Turnstone and Shelduck. 6% of all individuals were of major waterfowl prey species. These figures are only indicative, but show the availability of suitable prey species for colonisation of a new site.
Disturbance	Agricultural[1], nearby yacht moorings[1], some wildfowling[2].
Estimate of Bird Numbers Colonising Site	Predicted numbers using the site are lower than numbers displaced, particularly if muddy sediments are not deposited (Table 8.2.3.ii). Large areas of saltmarsh may favour Brent Geese. WeBS low tide count (1994/95) shows Shelduck, Dunlin and Redshank numbers are high nearby, but other species numbers are low or absent.

Table 8.2.3.i Environmental site characteristics for Site 3. Feldy Marshes. (Sources: 1: ABP Research 1998; 2: Buck 1997).

Species	Average numbers on adjacent count units (1994/95)	Numbers displaced from Lappel Bank and Fagbury Flats	Predicted bird numbers using site		
			Saltmarsh and mud	Saltmarsh and muddy sand	Saltmarsh and sand
CA	n/a	7	n/a	n/a	n/a
DB	1-50	349	155 (910)	155 (910)	155 (910)
SU	<200	127	65 (475)	23 (178)	19 (300)
MA	0	5	5 (184)	3 (44)	6 (112)
OC	<10	175	18 (331)	112 (344)	97 (1815)
RP	0	69	6 (256)	1 (35)	8 (151)
GV	0	133	27 (392)	12 (98)	50 (797)
L.	<2000	175	43 (1452)	5 (148)	6 (221)
KN	0	24	20 (1702)	123 (713)	113 (1121)
SS	0	4	0 (40)	0 (0)	0 (0)
DN	500-3000	3622	451 (4485)	100 (610)	193 (2631)
CU	<75	289	30 (493)	13 (74)	14 (99)
RK	<100	235	135 (1458)	34 (253)	40 (390)
TT	0	58	5 (356)	9 (191)	11 (269)
TOTAL		5272	960 (12534)	590 (3598)	712 (8816)

Table 8.2.3.ii Average numbers of birds on adjacent mudflats (low tide count 1994/95) and estimated bird numbers using Feldy Marshes after development, allowing for 82 ha saltmarsh and 48 ha mudflat (mud, muddy sand and sand). Numbers of Brent Geese estimated using low tide count whole estuary densities (Table 3.2.1.2); numbers of other species estimated using densities in Table 3.2.1.1.

[1]Area	Option 1: 72 ha saltmarsh, 98 ha mudflat. Option 2: 24 ha saltmarsh, 63 ha mudflat.
Situation	South bank of Blackwater estuary near mouth. Important species (see Table 8.2.3.i).
[1]Tidal Range	2.4 m (mean spring).
[1]Exposure	Site exposed to long north-easterly fetch and high tidal energy regime. General very exposed, but some protection provided by offshore barges[1].
Nature of Adjacent Intertidal Sediments	Coarse shell sand, saltmarsh to east and west[1].
Nature of Adjacent Intertidal Vegetation	Well developed saltmarsh to east and west[1].
Nature of Adjacent Intertidal Benthos	As for Site 3 (Tables 8.2.3.i & 8.2.11).
Disturbance	Public footpath, nuclear power station, agriculture[1].
Estimate of Bird Numbers Colonising Site	Very low numbers of birds were present in adjacent count units (Figure 8.2.3) and only of four species - Brent Geese (<25), Grey Plover (<25), Dunlin (<250) and Redshank (<25). Numbers predicted from mean south-east estuary densities (Table 8.2.4.ii & iii) are lower than numbers displaced. Hawever, if one or two species were to use the site at higher than average densities, it may hold sufficient numbers.

Table 8.2.4i Environmental site characteristics for Site 4. Weymarks Marshes. (Sources: 1: ABP Research 1998)

Species	Numbers displaced from Lappel Bank and Fagbury Flats	Predicted bird numbers using site		
		Saltmarsh and mud	Saltmarsh and muddy sand	Saltmarsh and sand
CA	7	n/a	n/a	n/a
DB	349	202 (1190)	202 (1190)	202 (1190)
SU	127	119 (831)	35 (226)	26 (475)
MA	5	7 (333)	3 (47)	9 (187)
OC	175	35 (613)	226 (639)	197 (3643)
RP	69	12 (487)	2 (38)	15 (274)
GV	133	50 (717)	20 (117)	98 (1544)
L.	175	82 (2792)	4 (130)	7 (279)
KN	24	41 (3475)	251 (1457)	231 (2288)
SS	4	0 (82)	0 (0)	0 (0)
DN	3622	910 (8856)	194 (944)	383 (5070)
CU	289	53 (948)	19 (92)	21 (144)
RK	235	247 (2716)	42 (255)	53 (535)
TT	58	7 (522)	15 (185)	20 (344)
TOTAL	5272	1765 (23562)	1013 (5320)	1262 (15973)

Table 8.2.4.ii Estimated bird numbers using Weymarks Marshes (Option 1) after development, allowing for 72 ha saltmarsh and 98 ha mudflat (mud, muddy sand and sand). Numbers of Brent Geese estimated using low tide count whole estuary densities (Table 3.2.1.2); numbers of other species estimated using densities in Table 3.2.1.1.

Species	Numbers displaced from Lappel Bank and Fagbury Flats	Predicted bird numbers using site		
		Saltmarsh and mud	**Saltmarsh and muddy sand**	**Saltmarsh and sand**
CA	7	n/a	n/a	n/a
DB	349	103 (609)	103 (609)	103 (609)
SU	127	74 (502)	19 (113)	13 (273)
MA	5	4 (204)	2 (20)	5 (110)
OC	175	22 (380)	145 (396)	127 (2327)
RP	69	8 (305)	1 (16)	10 (168)
GV	133	31 (442)	12 (56)	62 (973)
L.	175	52 (1755)	2 (44)	3 (139)
KN	24	26 (2234)	161 (936)	148 (1471)
SS	4	0 (53)	0 (0)	0 (0)
DN	3622	583 (5623)	122 (537)	244 (3189)
CU	289	33 (596)	11 (46)	12 (79)
RK	235	153 (1685)	20 (103)	27 (283)
TT	58	4 (287)	9 (71)	12 (173)
TOTAL	5272	1093 (14675)	607 (2947)	766 (9794)

Table 8.2.4.iii Estimated bird numbers using Weymarks Marshes (Option 2) after development, allowing for 72 ha saltmarsh and 98 ha mudflat (mud, muddy sand and sand). Numbers of Brent Geese estimated using low tide count whole estuary densities (Table 3.2.1.2); numbers of other species estimated using densities in Table 3.2.1.1.

[1]**Area**	69 ha saltmarsh, no mudflat.
Situation	South bank of the upper Blackwater estuary. Important species (see Table 8.2.3i).
[1]**Tidal Range**	2.4 m (mean spring).
[1]**Exposure**	Sheltered.
Nature of Adjacent Intertidal Sediments	Mudflats (historically saltmarsh)[1].
Nature of Adjacent Intertidal Vegetation	Cordgrass and algal cover ([1]*Enteromorpha)*.
Nature of Adjacent Intertidal Benthos	Data only available for the outer estuary (see Tables 8.2.3.i & 8.2.11) mudflats around this site are likely to hold similar species, but a full specific survey is recommended.
Disturbance	Public footpath, sailing, residential areas[1].
Estimate of Bird Numbers Colonising Site	Average numbers on adjacent areas (WeBS Low Tide Counts 1994/95) show that most species are present in reasonable numbers (Figure 8.2.3), with the exception of Oystercatcher, Curlew and Knot (Table 8.2.5.ii). However, numbers predicted from mean south-east estuary densities are very low as it is likely that the whole area will develop into saltmarsh.

Table 8.2.5.i Environmental site characteristics for Site 5. Nipsells. (Sources: 1: ABP Research 1998)

Species	Average numbers on adjacent count units (1994/95)	Numbers lost from Fagbury Flats and Lappel Bank	Predicted bird numbers using site
CA	n/a	7	n/a
DB	<500	349	82 (483)
SU	<100	127	9 (100)
MA	<100	5	2 (30)
OC	<10	175	1 (45)
RP	<5	69	0 (25)
GV	<25	133	3 (60)
L.	<750	175	4 (124)
KN	0	24	0 (0)
SS	0	4	0 (0)
DN	<500	3622	7 (217)
CU	<50	289	5 (42)
RK	<150	235	20 (189)
TT	<10	58	2 (149)
TOTAL		5272	135 (1464)

Table 8.2.5.ii Average numbers of birds on adjacent mudflats (low tide count 1994/95) and estimated bird numbers using Nipsells after development, allowing for 69 ha saltmarsh and no mudflat. Numbers of Brent Geese estimated using low tide count whole estuary densities (Table 3.2.1.2); numbers of other species estimated using densities in Table 3.2.1.1.

[1]Area	35 ha saltmarsh, 9 ha mudflat.
Situation	South bank of Blackwater estuary, mid-estuary.
[1]**Tidal Range**	2.4 m (mean spring).
[1]**Exposure**	Relatively sheltered.
Nature of Adjacent Intertidal Sediments	Open mudflats to front[1]. Saltmarsh eroded historically (1940's)[1].
Nature of Adjacent Intertidal Vegetation	No data available.
Nature of Adjacent Intertidal Benthos	Data only available for the outer estuary (see Tables 8.2.3.i & 8.2.11) mudflats around this site are likely to hold similar species, but a full specific survey is recommended.
Disturbance	Public footpath, agricultural, caravan park and boat-slip to west.
Estimate of Bird Numbers Colonising Site	Average numbers on adjacent areas (WeBS Low Tide Counts 1994/95) (Figure 8.2.3) show that most species are present in good numbers. Predicted numbers for the site are low given the small area of likely to develop.

Table 8.2.6.i Environmental site characteristics for Site 6. St. Lawrence Marshes. (Sources: 1: ABP Research 1998)

Species	Average numbers on adjacent count units (1994/95)	Numbers displaced from Lappel Bank and Fagbury Flats	Predicted bird numbers using site: Saltmarsh and mud	Saltmarsh and muddy sand	Saltmarsh and sand
CA	n/a	7	n/a	n/a	n/a
DB	<250	349	52 (308)	52 (308)	52 (308)
SU	<100	127	15 (117)	7 (62)	6 (85)
MA	<25	5	1 (43)	1 (17)	2 (30)
OC	<10	175	4 (75)	21 (77)	19 (353)
RP	<5	69	1 (55)	0 (14)	2 (35)
GV	<25	133	6 (90)	3 (35)	10 (166)
L.	<50	175	9 (307)	2 (63)	2 (77)
KN	<750	24	4 (319)	23 (134)	21 (210)
SS	0	4	0 (8)	0 (0)	0 (0)
DN	<750	3622	87 (903)	21 (176)	38 (555)
CU	<50	289	7 (104)	4 (26)	4 (30)
RK	<25	235	31 (327)	12 (101)	13 (127)
TT	<10	58	2 (109)	2 (78)	3 (93)
TOTAL		5272	219 (2765)	148 (1091)	172 (2069)

Table 8.2.6.ii Average numbers of birds on adjacent mudflats (low tide count 1994/95) and estimated bird numbers using St Lawrence Marshes after development, allowing for 35 ha saltmarsh and 9 ha mudflat (mud, muddy sand and sand). Numbers of Brent Geese estimated using low tide count whole estuary densities (Table 3.2.1.2); numbers of other species estimated using densities in Table 3.2.1.1.

[1]Area	30 ha saltmarsh, 103 ha mudflat.
Situation	South bank of outer Ore estuary.
[1]Tidal Range	1.45 m (mean spring).
[1]Exposure	Sheltered.
Nature of Adjacent Intertidal Sediments	Fronted by saltmarsh, but eroding at 0.3 m per year[1].
Nature of Adjacent Intertidal Vegetation	No data available.
Nature of Adjacent Intertidal Benthos	No data available.
Disturbance	Public footpath along perimeter wall, near RSPB reserve, yachting, agricultural.
Estimate of Bird Numbers Colonising Site	The 5 year mean high tide counts (waders only) at adjacent sites (Table 8.2.7.ii) suggest that most species are regularly present nearby. Numbers predicted from south-east estuary densities are lower that those to be compensated for, but birds may use the area at higher than mean densities if suitable sediments develop.

Table 8.2.7.i Environmental site characteristics for Site 7. Boyton Marsh. (Sources: 1: ABP Research 1998)

Species	Peak mean numbers	Numbers displaced from Lappel Bank and Fagbury Flats	Predicted bird numbers using site: Saltmarsh and mud	Saltmarsh and muddy sand	Saltmarsh and sand
CA	n/a	7	n/a	n/a	n/a
DB		349	158 (931)	158 (931)	158 (931)
SU		127	119 (808)	30 (171)	21 (433)
MA	*	5	6 (330)	2 (29)	9 (176)
OC	17	175	36 (615)	237 (642)	207 (3799)
RP	2	69	12 (496)	2 (23)	16 (271)
GV	49	133	50 (714)	19 (83)	101 (1583)
L.	505	175	84 (2853)	2 (55)	4 (211)
KN	9	24	43 (3652)	264 (1531)	243 (2405)
SS	0	4	0 (86)	0 (0)	0 (0)
DN	237	3622	952 (9164)	199 (848)	398 (5185)
CU	176	289	53 (968)	17 (69)	19 (123)
RK	77	235	247 (2729)	31 (143)	42 (437)
TT	6	58	6 (450)	14 (96)	19 (263)
TOTAL		5272	1766 (23796)	975 (4621)	1237 (15817)

Table 8.2.7.ii Peak mean numbers of birds on adjacent areas (five- year peak mean high tide count) and estimated bird numbers using Boyton Marshes after development, allowing for 30 ha saltmarsh and 103 ha mudflat (mud, muddy sand and sand). Numbers of Brent Geese estimated using low tide count whole estuary densities (Table 3.2.1.2); numbers of other species estimated using densities in Table 3.2.1.1.

[1]**Area**	8 ha saltmarsh, 8 ha mudflat.
Situation	North bank of the Orwell estuary, near the mouth and Port of Felixstowe. The Orwell holds internationally important numbers of Redshank and nationally important populations of Brent Geese, Shelduck, Ringed Plover and Dunlin (Table 2.1.3).
[1]**Tidal Range**	2.2 m (mean spring).
[1]**Exposure**	Relatively sheltered.
Nature of Adjacent Intertidal Sediments	Fine silt and mud, but foreshore eroding and being replaced by gravel[1].
Nature of Adjacent Intertidal Vegetation	No data available.
Nature of Adjacent Intertidal Benthos	Data available for intertidal fauna for the whole Orwell estuary (1988) and lower Orwell estuary (1995) (Table 8.2.11). 23-33% of species of benthic invertebrates were of waterfowl prey species, and 5-9.6% of total numbers of invertebrates were of favoured prey species. These figures are indicative only of the availability for colonisation of new areas of suitable prey species.
Disturbance	Bridleway and public footpath, agriculture, waterskiing, yachting.
Estimate of Bird Numbers Colonising Site	Numbers predicted from mean south-east estuary densities are very low. Densities on adjacent mudflats (WeBS low tide counts 1996/7) are similar to those used in these predictions (Table 8.2.8.ii).

Table 8.2.8.i Environmental site characteristics for Site 8. Trimley Marsh. (Sources: 1: ABP Research 1998)

Species	Density on adjacent mudflats ha^{-1}	Numbers displaced from Lappel Bank and Fagbury Flats	Predicted bird numbers using site: Saltmarsh and mud	Saltmarsh and muddy sand	Saltmarsh and sand
CA	n/a	7	n/a	n/a	n/a
DB	<3.2	349	19 (112)	19 (112)	19 (112)
SU	<0.2	127	10 (71)	3 (21)	2 (42)
MA	<16	5	1 (28)	0 (5)	1 (16)
OC	<0.8	175	3 (51)	19 (54)	16 (299)
RP	<0.8	69	1 (41)	0 (4)	1 (23)
GV	<0.8	133	4 (60)	2 (11)	8 (128)
L.	0	175	7 (232)	0 (14)	1 (27)
KN	0	24	3 (284)	21 (119)	19 (187)
SS	0	4	0 (7)	0 (0)	0 (0)
DN	<12.8	3622	75 (730)	16 (84)	31 (421)
CU	<0.2	289	5 (79)	2 (9)	2 (13)
RK	<1.6	235	21 (228)	4 (27)	5 (49)
TT	<0.8	58	1 (47)	1 (20)	2 (33)
TOTAL		5272	150 (1970)	87 (480)	107 (1350)

Table 8.2.8.ii Densities of birds on adjacent mudflats (WeBS low tide count 1996/7) and estimated bird numbers using Trimley Marshes after development, allowing for 8 ha saltmarsh and 8 ha mudflat (mud, muddy sand and sand). Numbers of Brent Geese estimated using low tide count whole estuary densities (Table 3.2.1.2); numbers of other species estimated using densities in Table 3.2.1.1.

[1]**Area**	28 ha saltmarsh, 26 ha mudflat.
Situation	South bank of the Orwell estuary, opposite Trimley Marsh (Site 8). The Orwell holds internationally and nationally important numbers of waterfowl (see Table 8.2.8.i).
[1]**Tidal Range**	2.2 m (mean spring).
[1]**Exposure**	Relatively sheltered.
Nature of Adjacent Intertidal Sediments	Fine mud/silt with sandy patches[1].
Nature of Adjacent Intertidal Vegetation	High *Enteromorpha* cover over mudflats[1], saltmarsh to east and west - eroding at 0.1-0.2 m per year[1].
Nature of Adjacent Intertidal Benthos	As for Site 8 (Table 8.2.8.i).
Disturbance	Public footpaths, agriculture, yachting.
Estimate of Bird Numbers Colonising Site	Numbers predicted from mean south-east estuary densities are very low. Densities on adjacent mudflats (WeBS low tide counts 1996/7) are similar to those used in these predictions (Table 8.2.9.ii).

Table 8.2.9.i Environmental site characteristics for Site 9. Shotley Marsh. (Sources: 1: ABP Research 1998)

Species	Density on adjacent mudflats ha^{-1}	Numbers displaced from Lappel Bank and Fagbury Flats	Predicted bird numbers using site: Saltmarsh and mud	Saltmarsh and muddy sand	Saltmarsh and sand
CA	n/a	7	n/a	n/a	n/a
DB	<3.2	349	64 (378)	64 (378)	64 (378)
SU	<0.2	127	33 (233)	10 (73)	8 (139)
MA	<0.2	5	2 (92)	1 (16)	3 (54)
OC	<0.8	175	9 (169)	60 (175)	53 (972)
RP	<0.8	69	3 (133)	1 (13)	4 (76)
GV	<0.8	133	14 (198)	6 (39)	26 (417)
L.	<3.2	175	22 (757)	2 (51)	2 (90)
KN	0	24	11 (922)	67 (386)	61 (607)
SS	0	4	0 (22)	0 (0)	0 (0)
DN	<12.8	3622	242 (2378)	52 (278)	103 (1373)
CU	<0.2	289	15 (257)	6 (278)	6 (44)
RK	<1.6	235	68 (745)	14 (30)	17 (166)
TT	<0.8	58	2 (158)	4 (92)	6 (110)
TOTAL		5272	485 (6442)	287 (1599)	353 (4426)

Table 8.2.9.ii Densities of birds on adjacent mudflats (WeBS low tide count 1996/7) and estimated bird numbers using Shotley Marshes after development, allowing for 28 ha saltmarsh and 26 ha mudflat (mud, muddy sand and sand). Numbers of Brent Geese estimated using low tide count whole estuary densities (Table 3.2.1.2); numbers of other species estimated using densities in Table 3.2.1.1.

Site	Predicted means	% of target	Predicted peaks	% of target
St Mary's	1753	33	23292	442
Blacketts	750	14	10072	191
Feldy	960	18	12534	238
Weymarks (1)	1765	33	23562	447
Weymarks (2)	1093	21	14675	278
Nipsells	135	3	1464	28
St Lawrence	219	4	2765	52
Boyton	1766	33	23796	451
Trimley	150	3	1970	37
Shotley	485	9	6442	122
Lappel & Fagbury	729	14	10045	191

Table 8.2.10 Predicted waterfowl numbers based on mean and peak densities (Table 3.2.1.1) as a percentage of the target numbers needed to replace the birds that had been present on Fagbury Flats and Lappel Bank.

Species	Blackwater		Orwell					
	Number of individuals	Percentage of total numbers	Upper (1988)		Lower (1988)		Lower (1995)	
			No.	%	No.	%	No.	%
Nereis spp.	31	0.8	496	4.0	65	17	15	0.5
Nephtys spp.	9	0.2	2	<0.1	3	<0.1	3	<0.1
Arenicola	1	<0.1	-	-	-	-	-	-
Corophium	73	2.0	128	1.0	1	<0.1	5	<0.1
Carcinus	10	0.3	1	<0.1	0	0	1	<0.1
Hydrobia	70	1.9	182	1.4	9	0.2	58	1.9
Mytilus	6	0.2	-	-	-	-	0	0
Cerastoderma (=Cardium)	12	0.3	71	0.5	64	1.7	3	<0.1
Macoma	4	0.1	263	2.0	56	1.5	3	<0.1
Scrobicularia	9	0.2	-	-	-	-	-	-
Mya	0	0	100	0.8	0	0	133	4.3
Total of all species	3,718	6	12,972	9.6	3,834	5.2	3,110	7.1
Number of prey species/ Total number of species (%)	10/ 69 = 14.5		8/ 35 = 22.9		6/18 = 33.3		8/ 24 = 33.3	

Table 8.2.11 Summary of intertidal benthos found in core samples in the Blackwater and Orwell estuaries. Blackwater data combined from five sites in the lower estuary - collected 1996. Orwell data for 27 sites combined (1988) (whole estuary) and three sites (1995) (lower estuary). Data supplied by ABP Research.

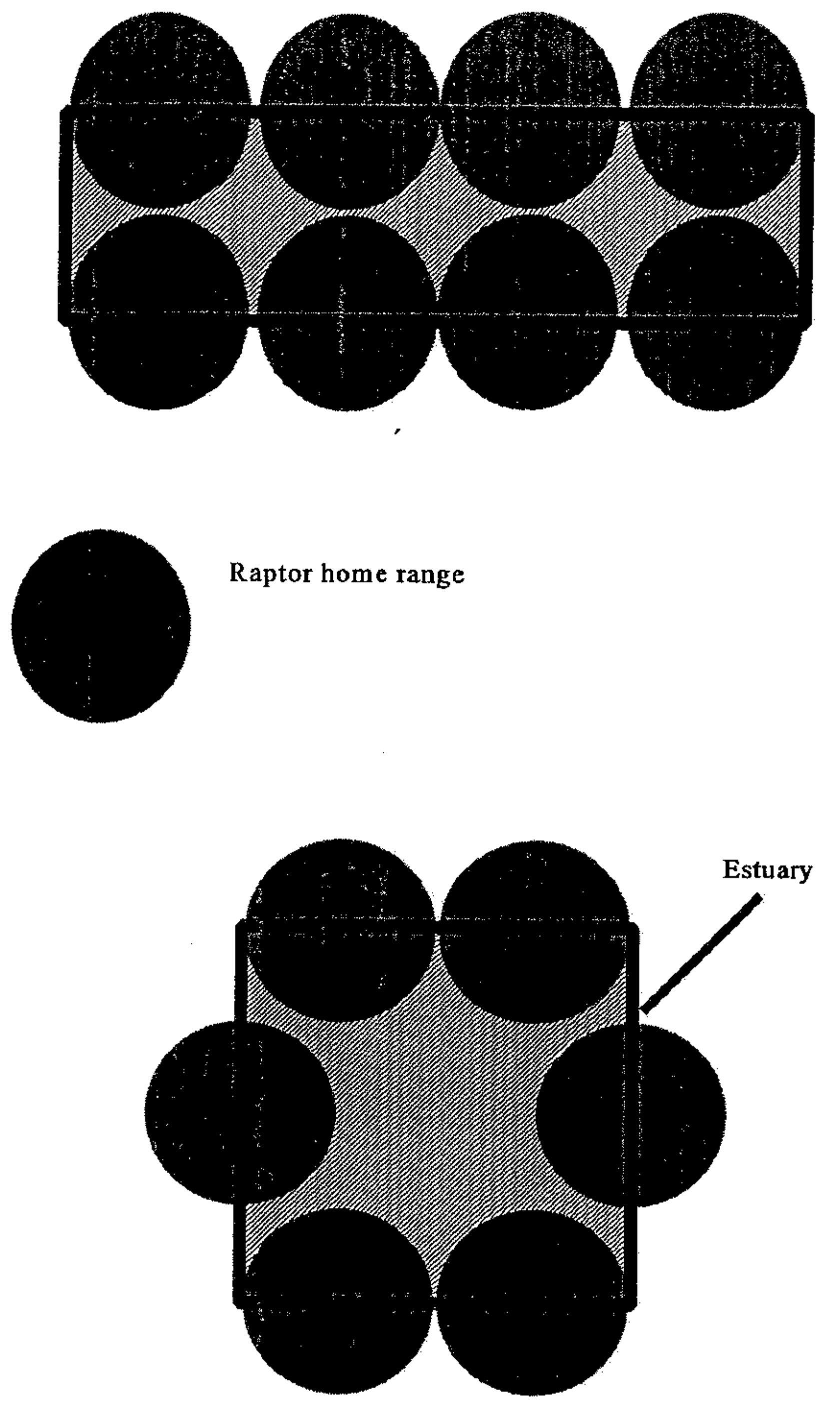


Figure 2.1 The effect of estuary shape on the proportion of each estuary which is relatively free of raptor disturbance.

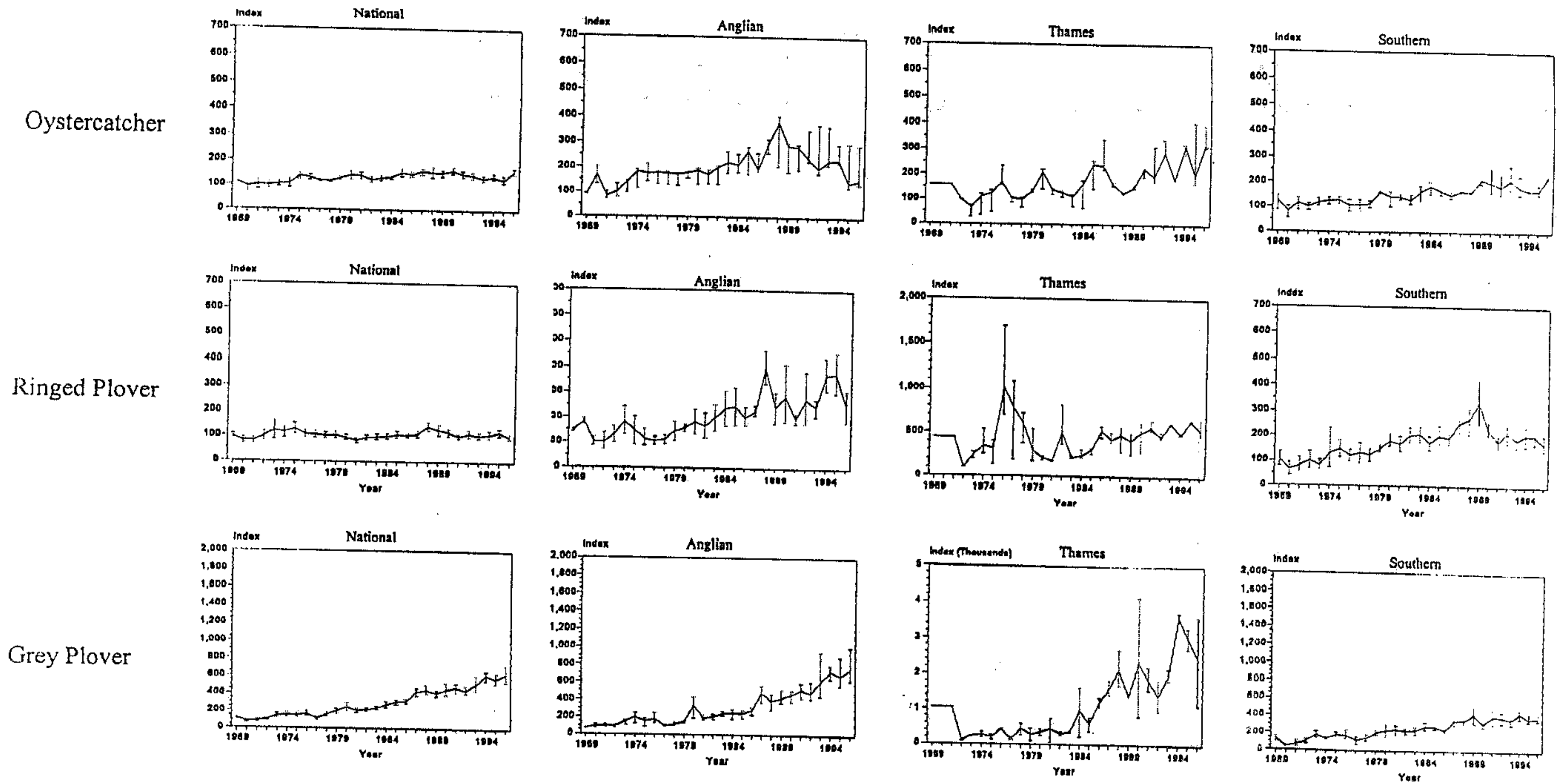


Figure 2.3.1 National and regional population indices for some British wintering waders (Austin *et al.* 1997)

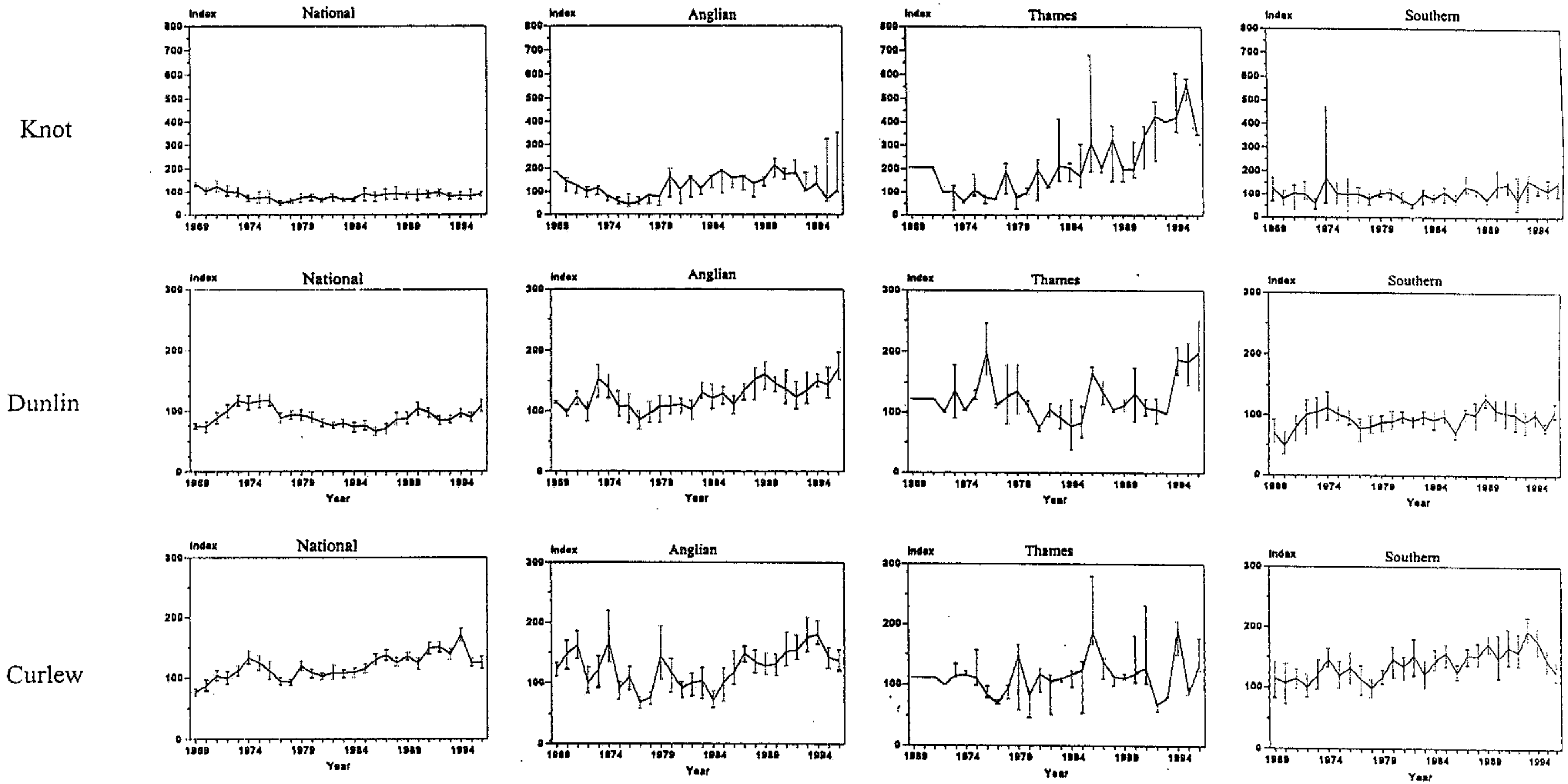
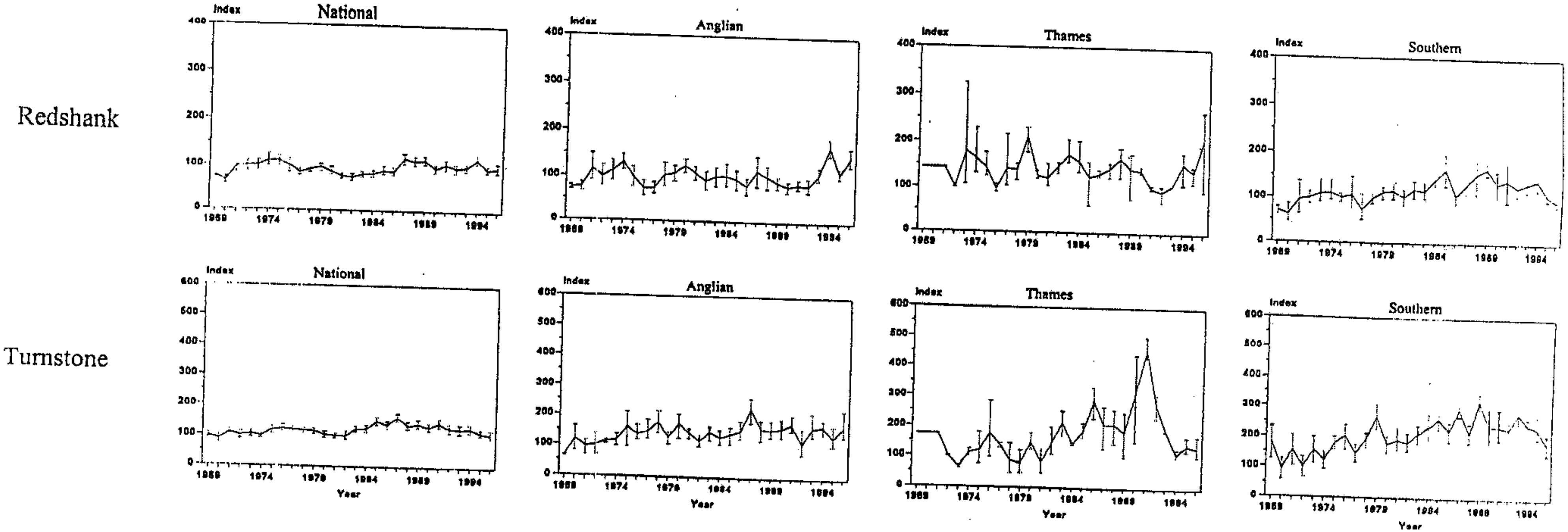


Figure 2.3.1 (Cont.) National and regional population indices for some British wintering waders (Austin *et al.* 1997)



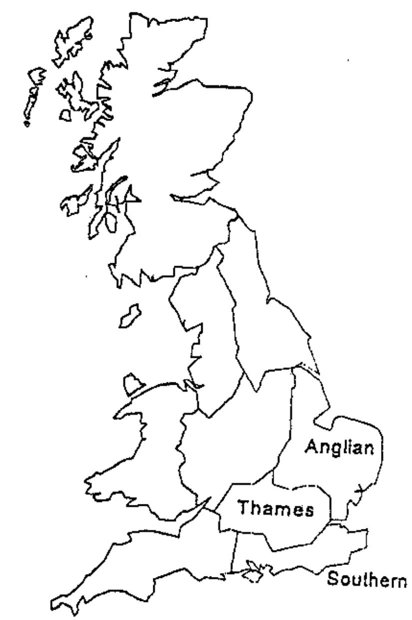
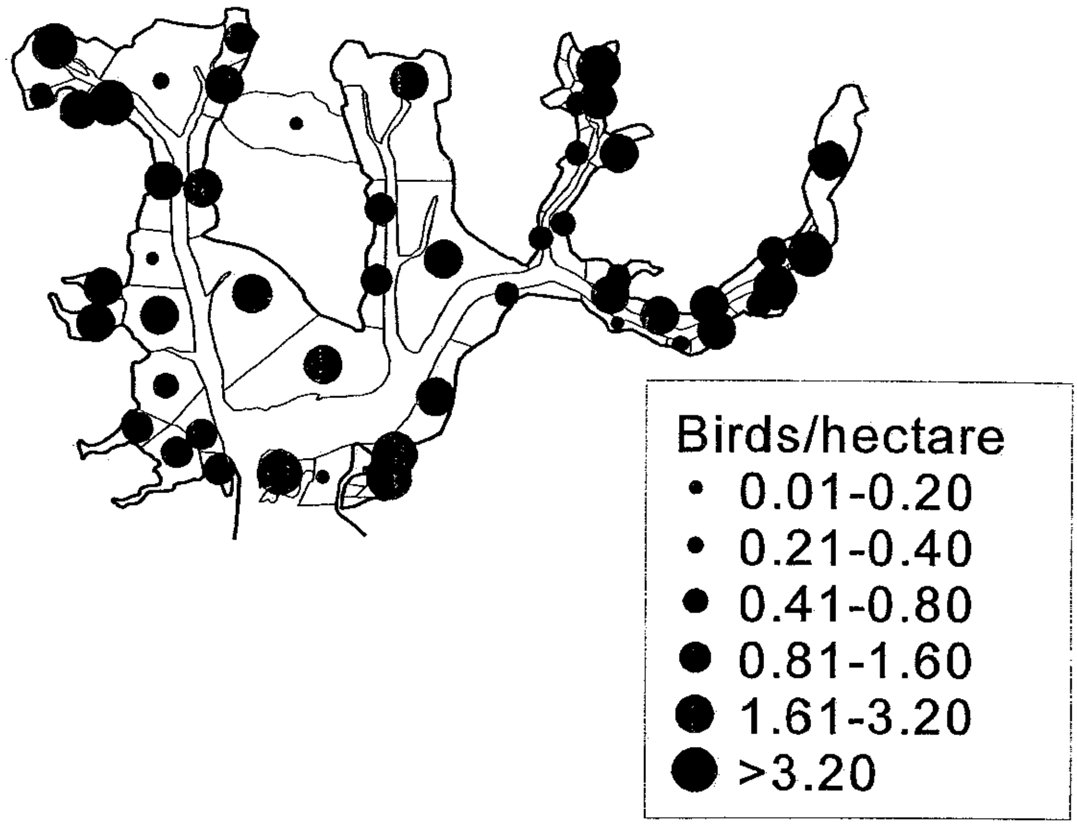


Figure 2.3.1 (Cont.) National and regional population indices for some British wintering waders (Austin *et al.* 1997)

Chichester Harbour (1996-97)



Stour Estuary (1996-97)

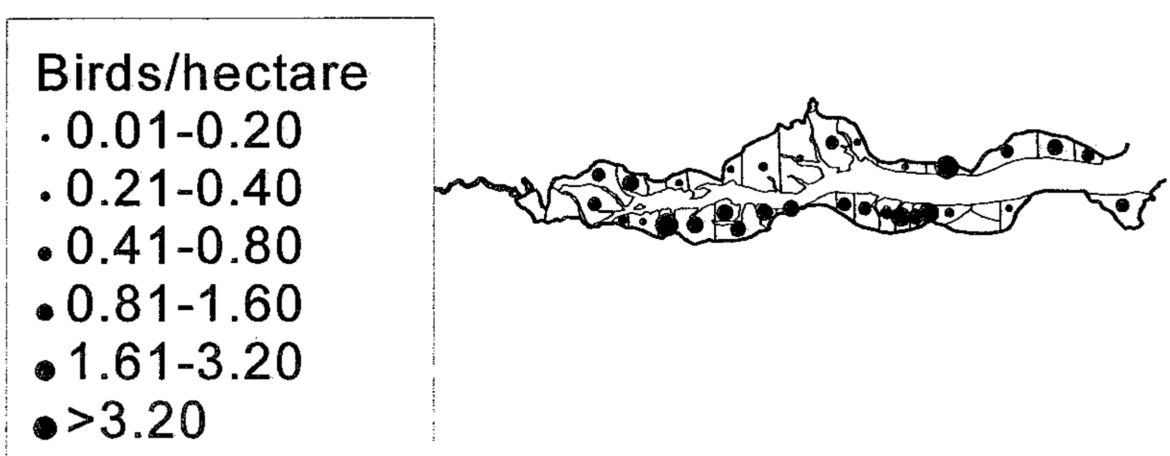
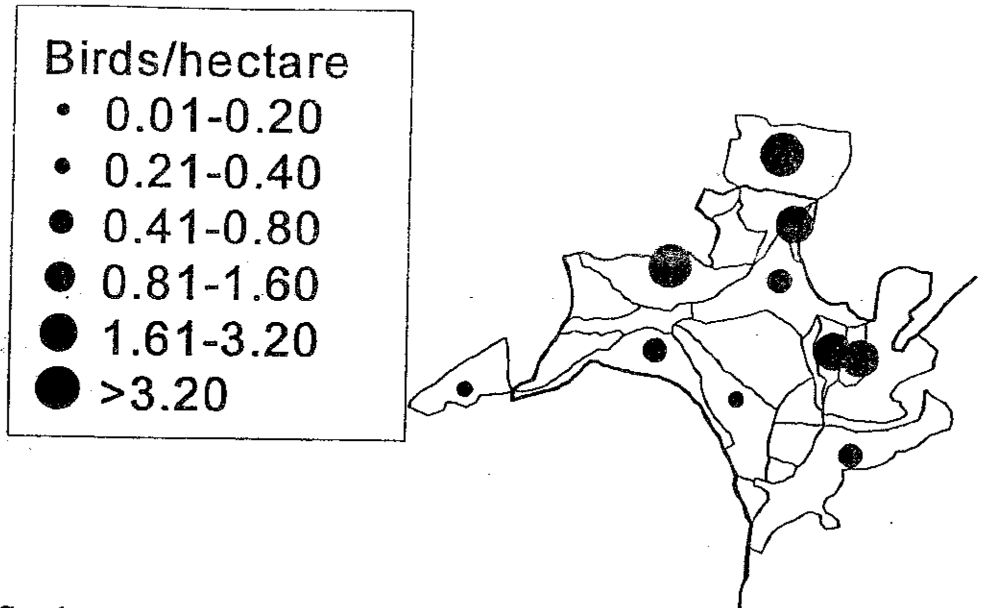


Figure 7.1.i The distribution of Dark-bellied Brent Geese on Chichester Harbour and the Stour Estuary (based on WeBS Low Tide Counts).

Pagham Harbour (1996-97)



Southampton Water (1996-97)

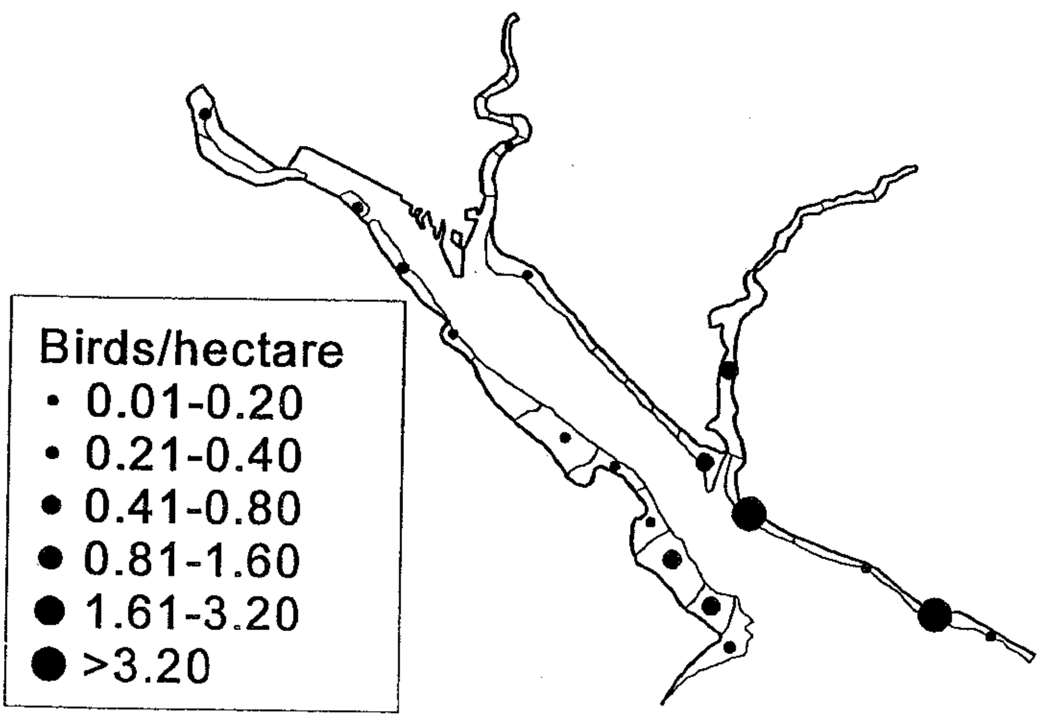
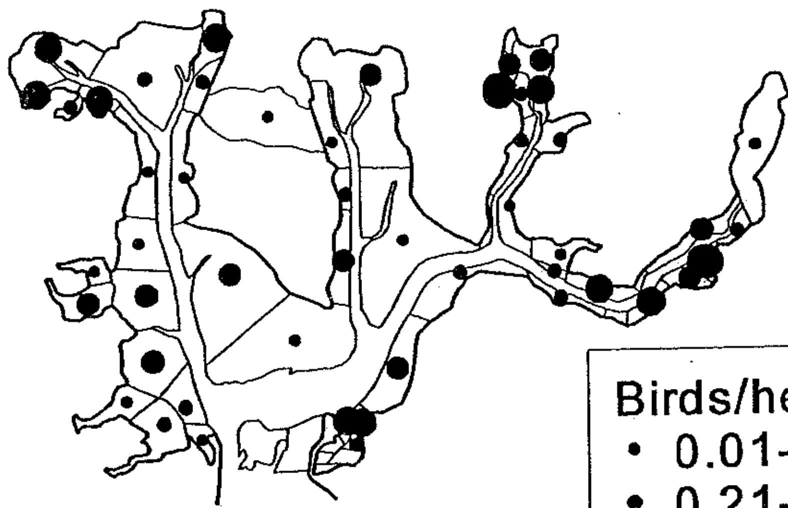


Figure 7.1.ii The distribution of Dark-bellied Brent Geese on Pagham Harbour and Southampton Water (based on WeBS Low Tide Counts).

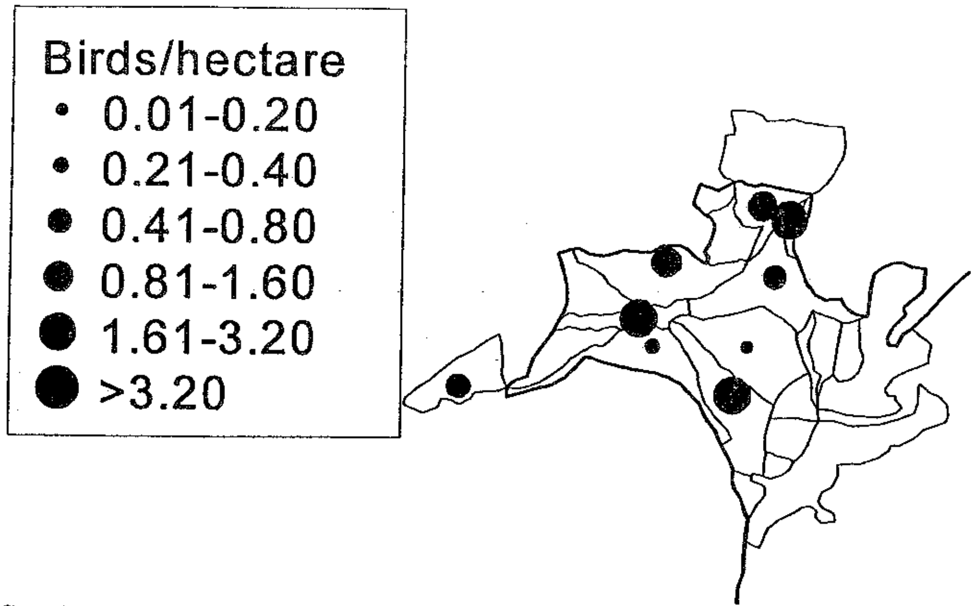
Chichester Harbour (1996-97)



Stour Estuary (1996-97)

Figure 7.1.iii The distribution of Shelduck on Chichester Harbour and the Stour Estuary (based on WeBS Low Tide Counts).

Pagham Harbour (1996-97)



Southampton Water (1996-97)

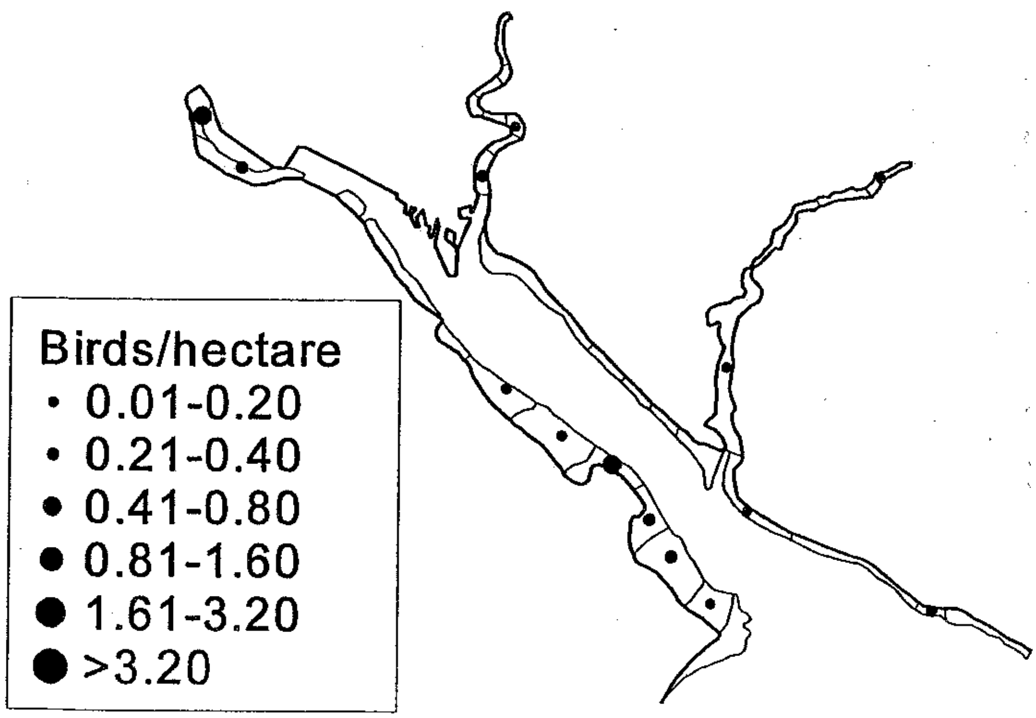
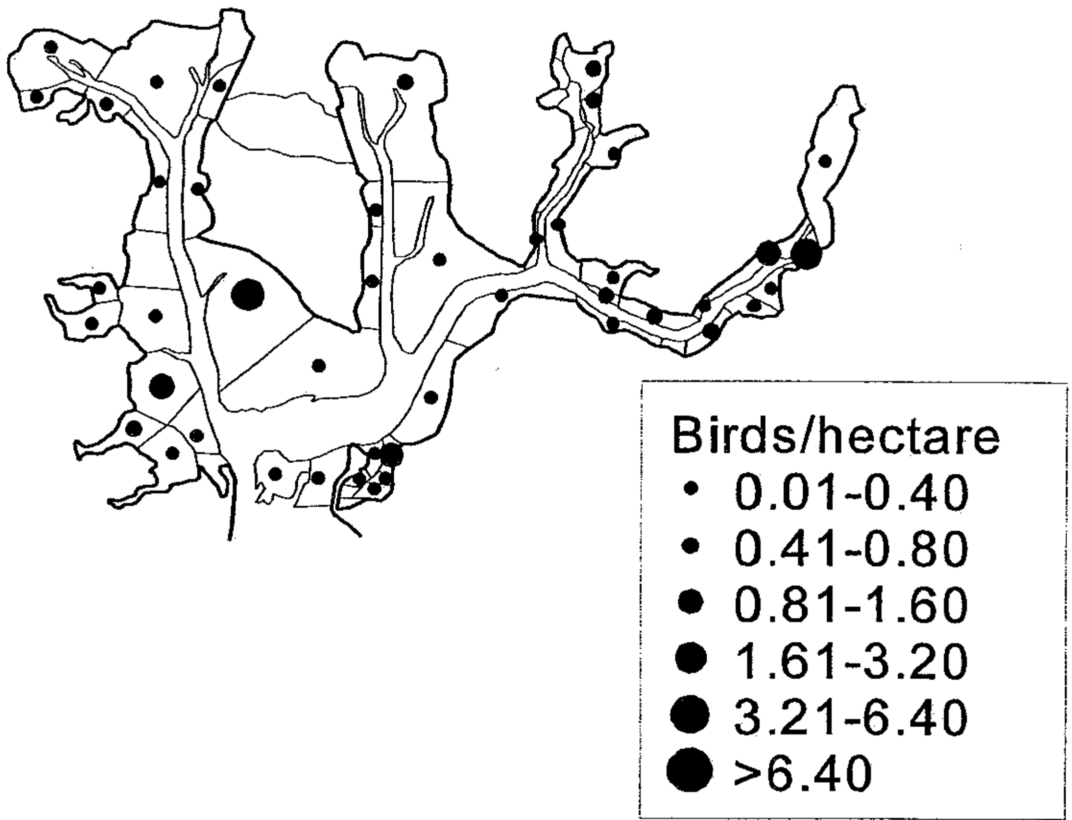


Figure 7.1.iv The distribution of Shelduck on Pagham Harbour and Southampton Water (based on WeBS Low Tide Counts).

Chichester Harbour (1996-97)



Stour Estuary (1996-97)

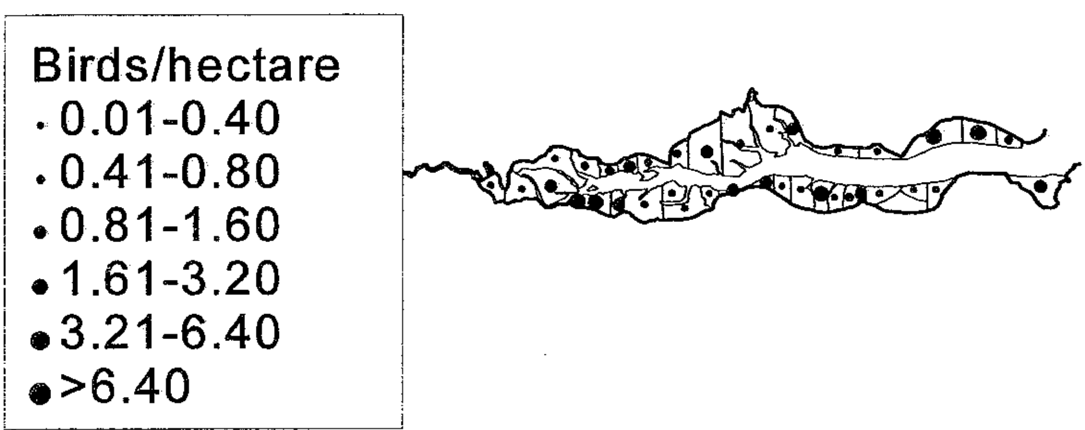
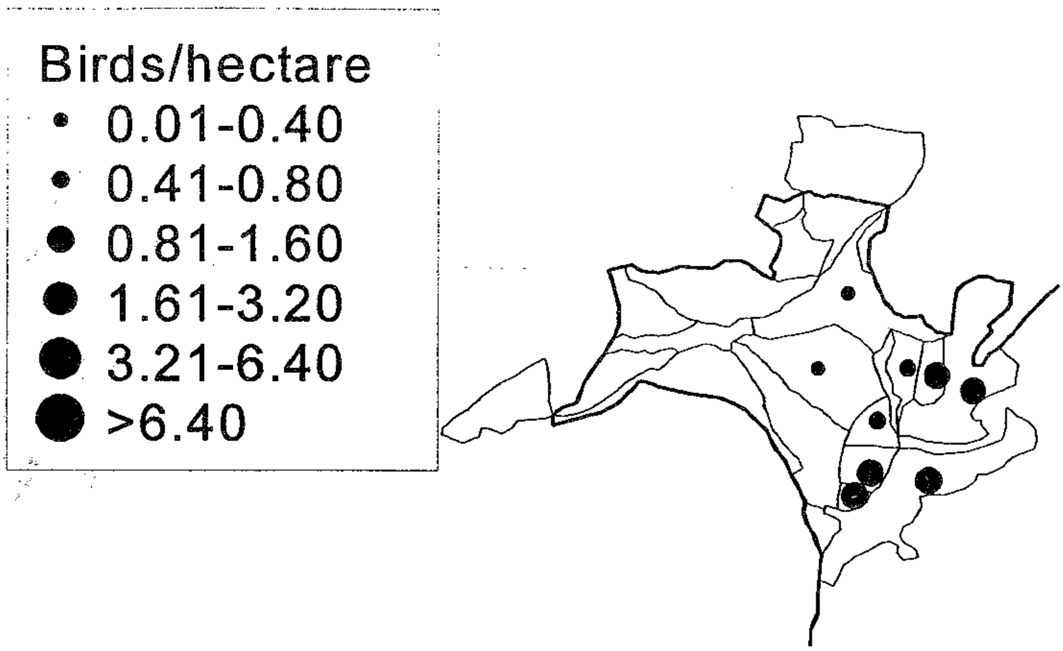


Figure 7.1.v The distribution of Oystercatcher on Chichester Harbour and the Stour Estuary (based on WeBS Low Tide Counts).

Pagham Harbour (1996-97)



Southampton Water (1996-97)

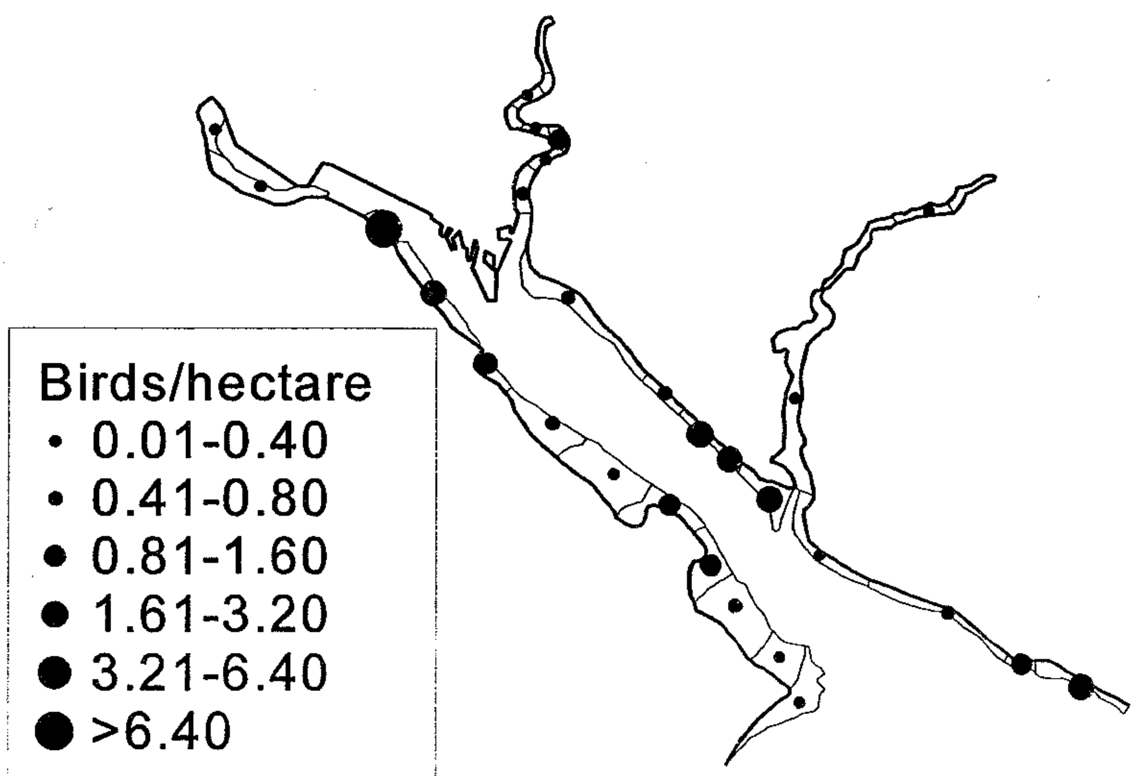
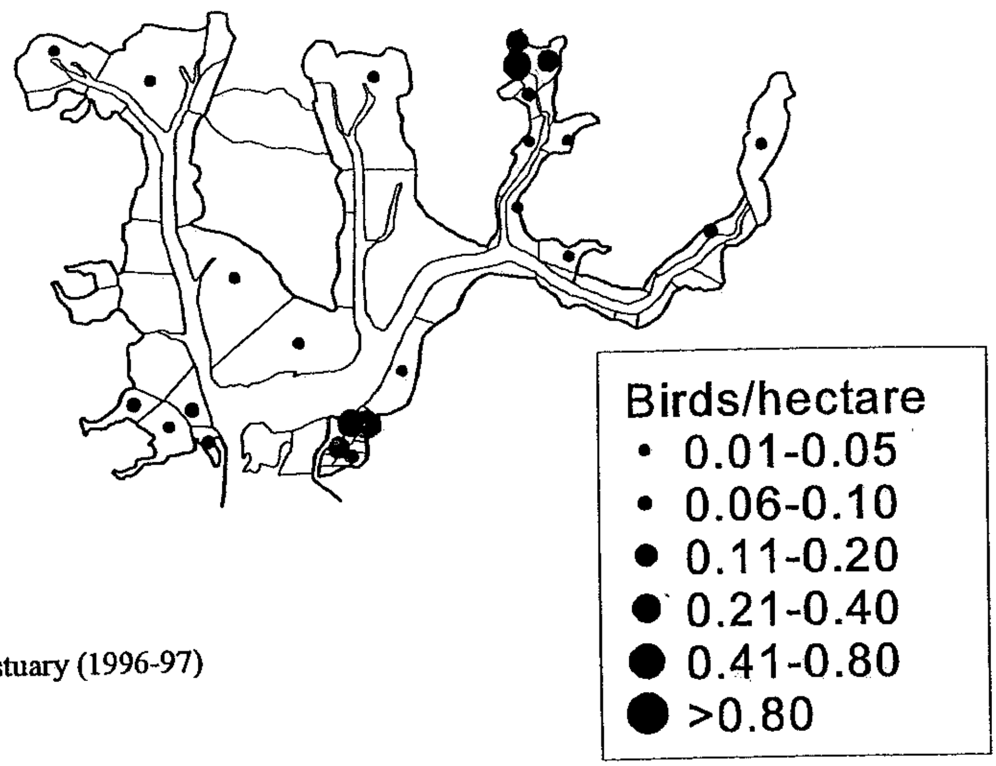


Figure 7.1.vi The distribution of Oystercatcher on Pagham Harbour and Southampton Water (based on WeBS Low Tide Counts).

Chichester Harbour (1996-97)



Stour Estuary (1996-97)

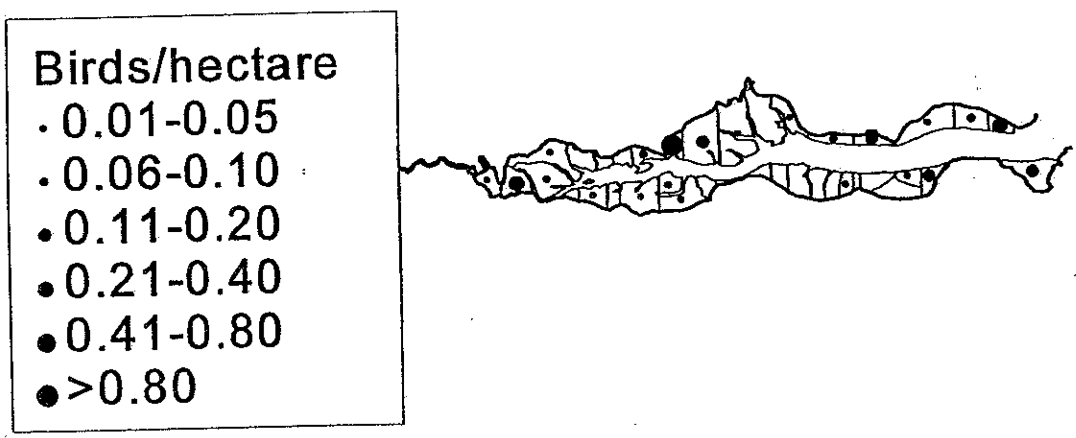
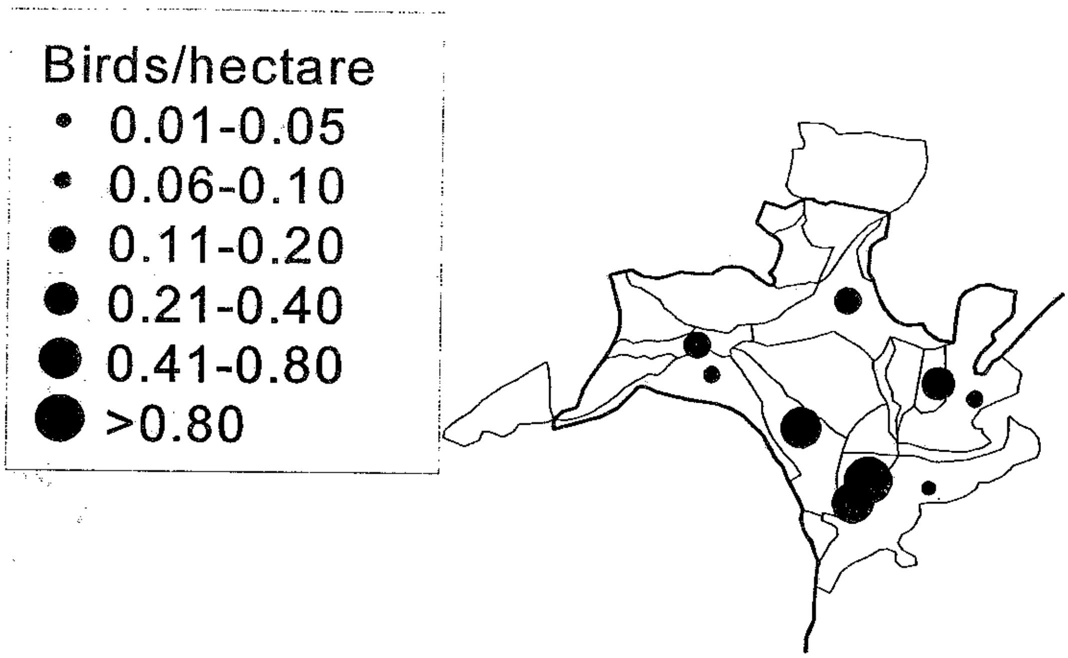


Figure 7.1.vii The distribution of Ringed Plover on Chichester Harbour and the Stour Estuary (based on WeBS Low Tide Counts).

Pagham Harbour (1996-97)



Southampton Water (1996-97)

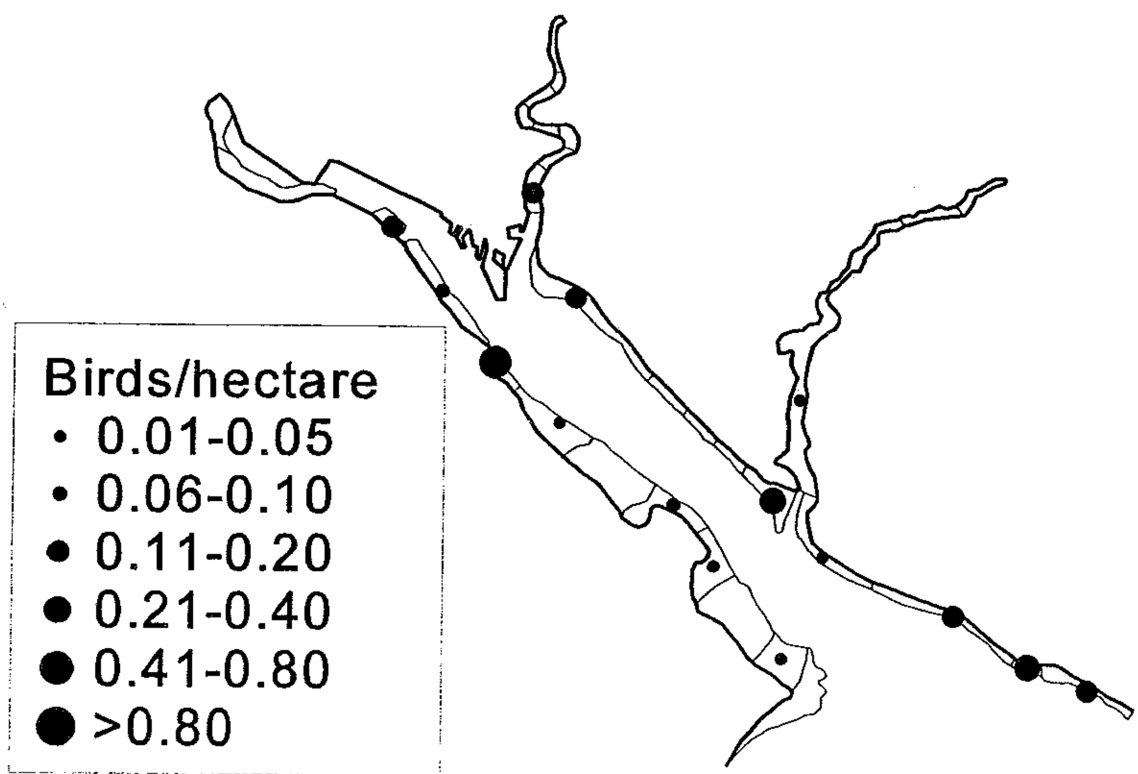
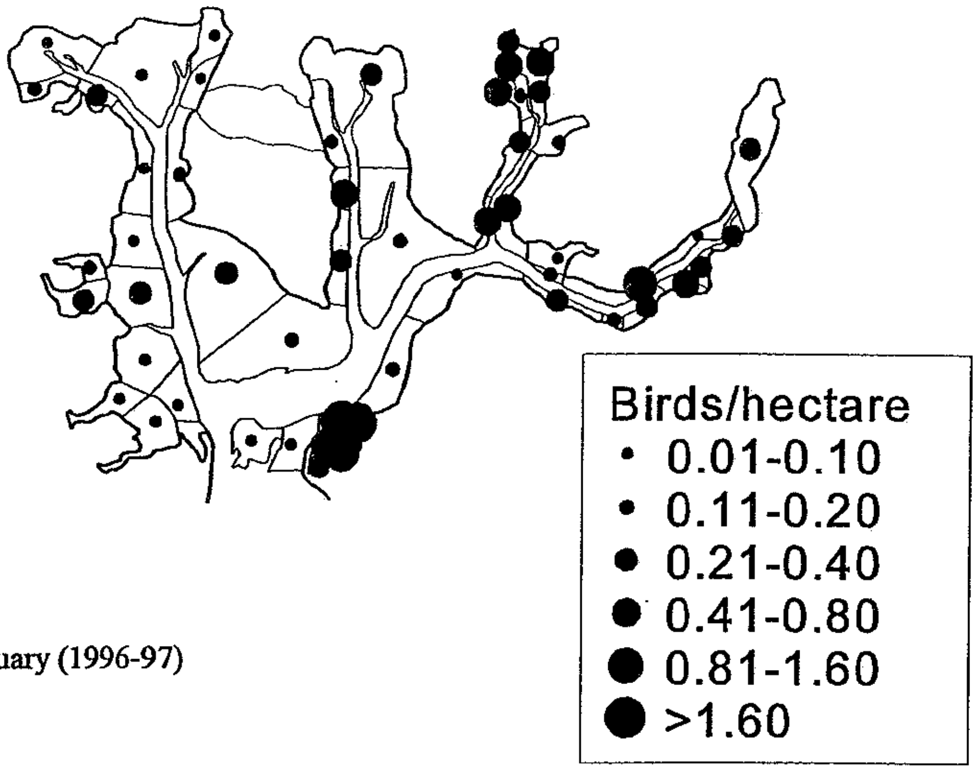


Figure 7.1.viii The distribution of Ringed Plover on Pagham Harbour and Southampton Water (based on WeBS Low Tide Counts).

Chichester Harbour (1996-97)



Stour Estuary (1996-97)

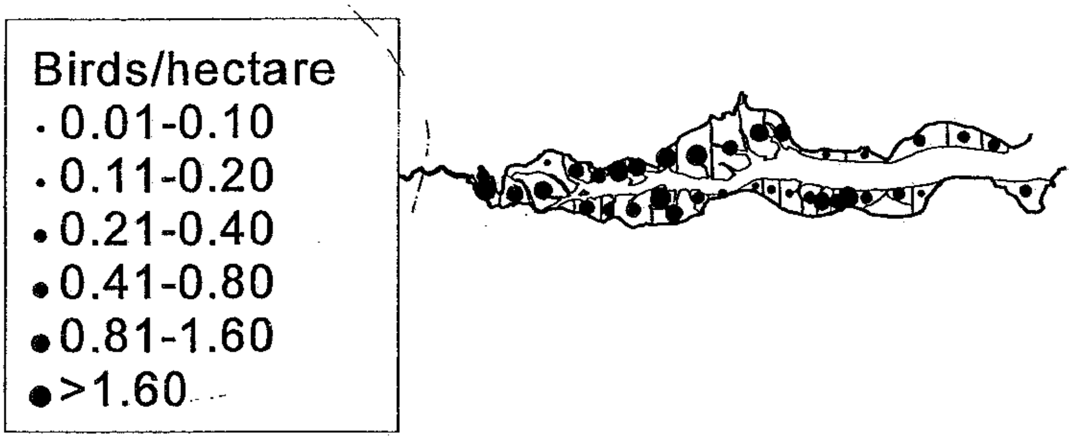
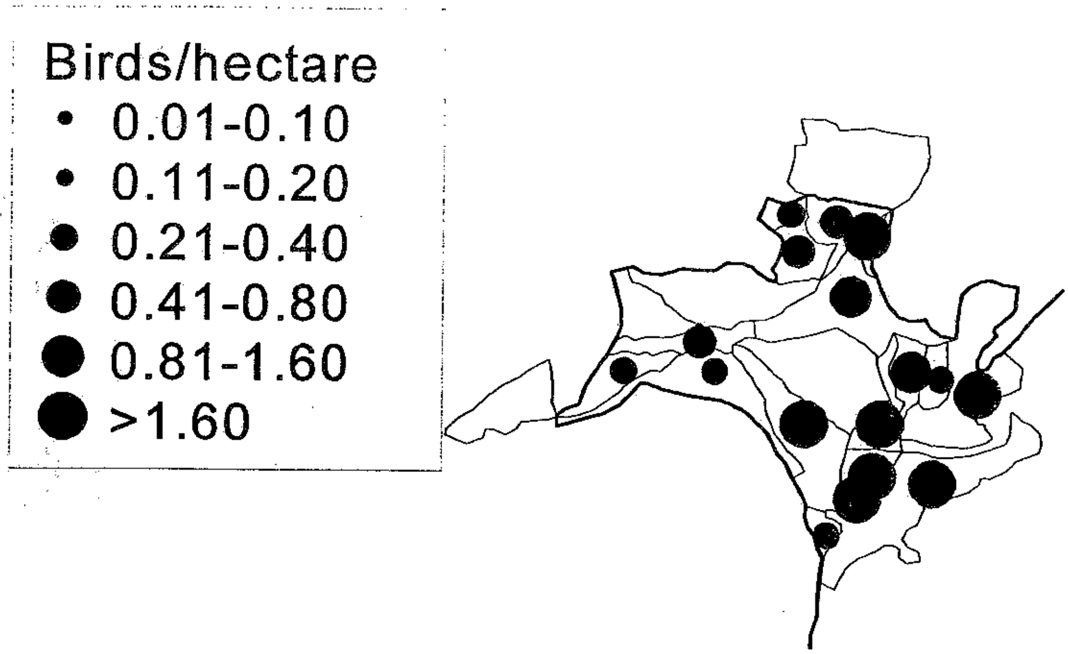


Figure 7.1.ix The distribution of Grey Plover on Chichester Harbour and the Stour Estuary (based on WeBS Low Tide Counts).

Pagham Harbour (1996-97)



Southampton Water (1996-97)

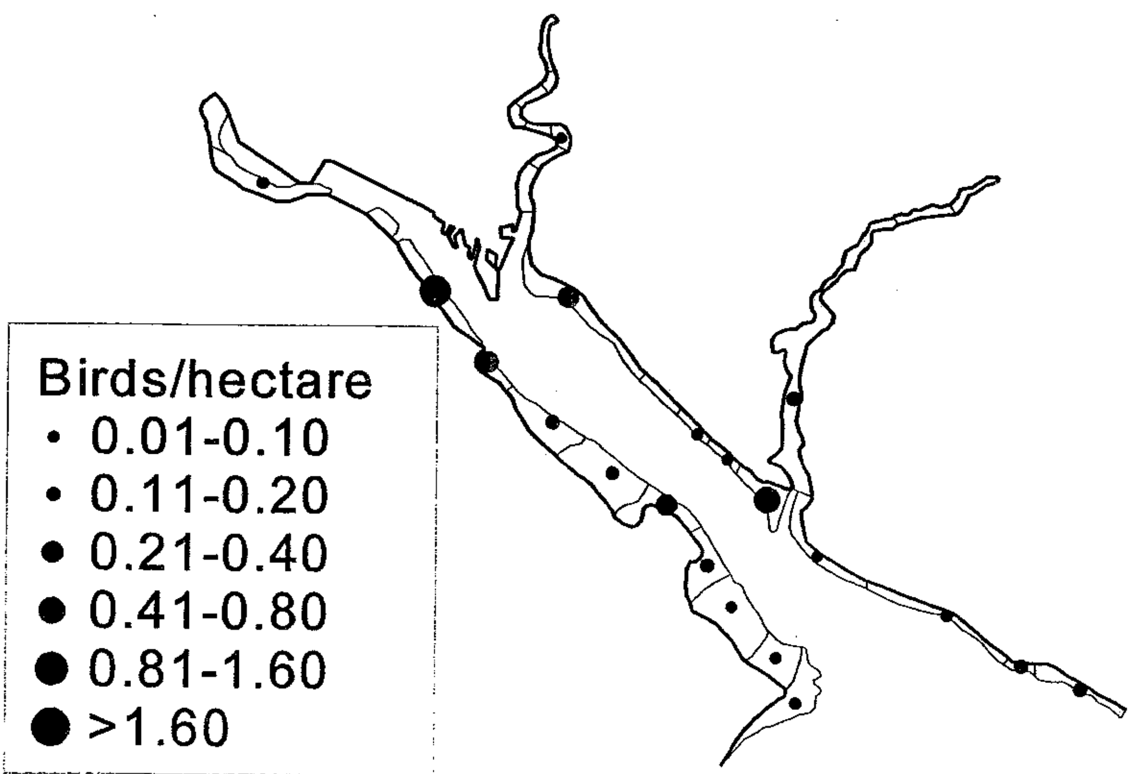
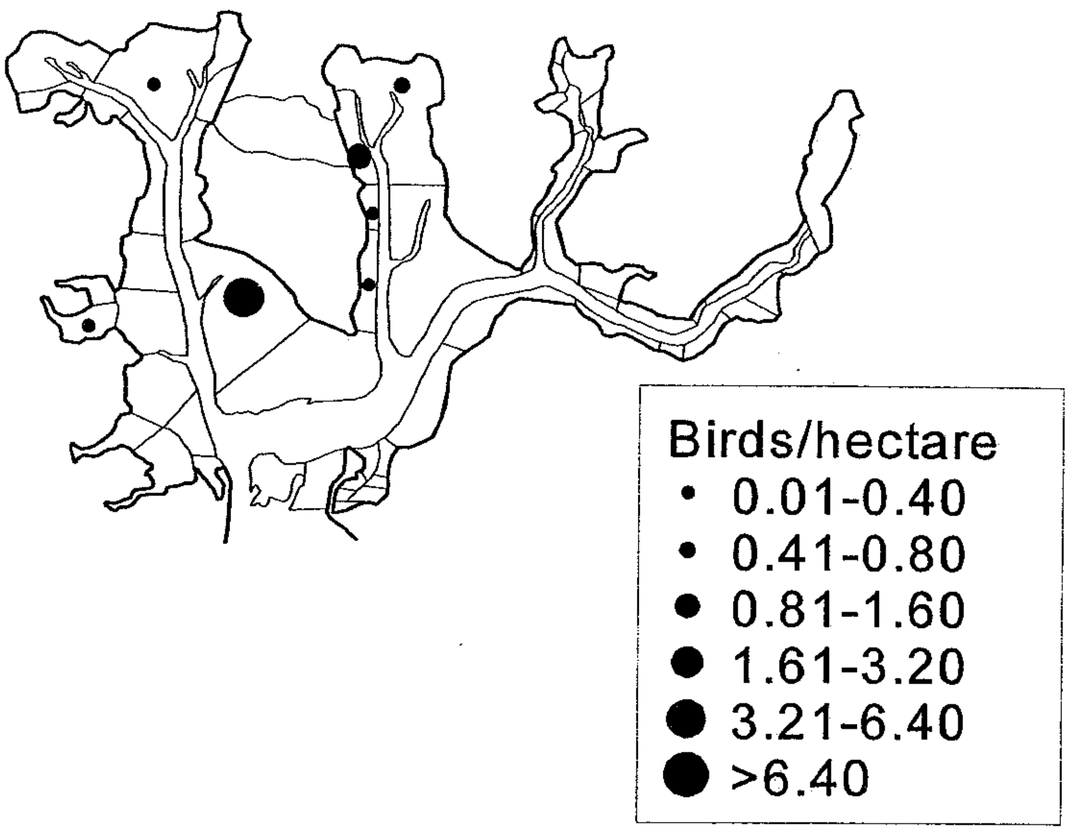


Figure 7.1.x The distribution of Grey Plover on Pagham Harbour and Southampton Water (based on WeBS Low Tide Counts).

Chichester Harbour (1996-97)



Stour Estuary (1996-97)

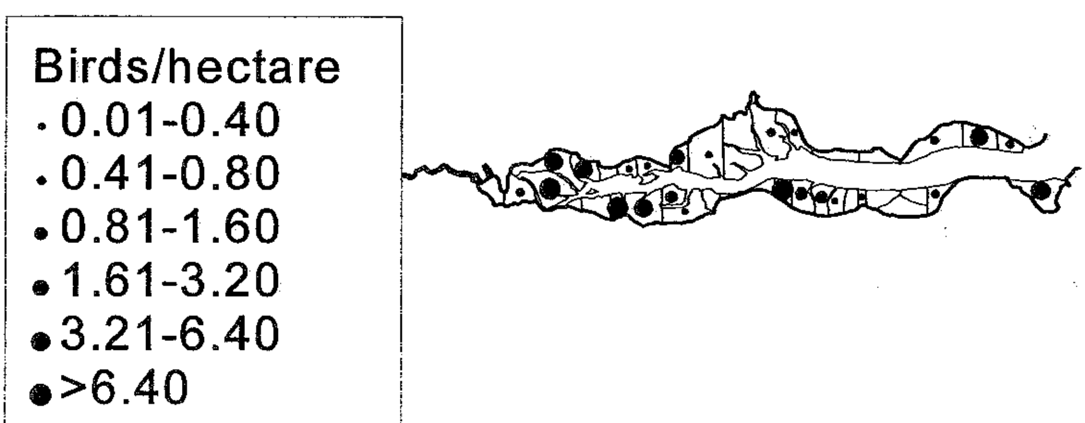
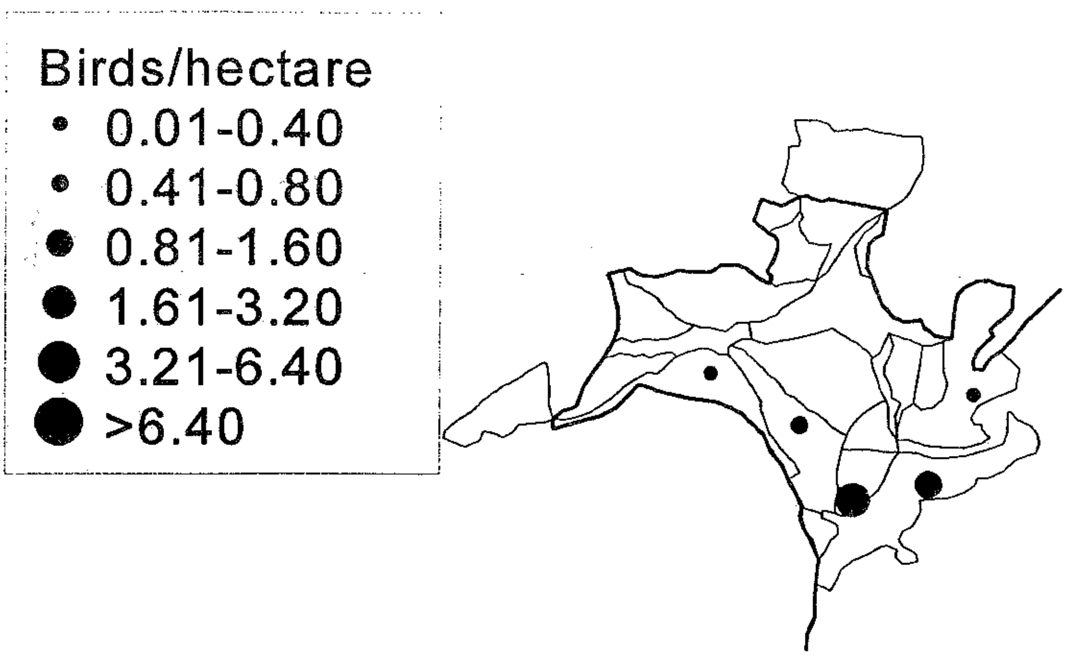


Figure 7.1.xi The distribution of Knot on Chichester Harbour and the Stour Estuary (based on WeBS Low Tide Counts).

Pagham Harbour (1996-97)



Southampton Water (1996-97)

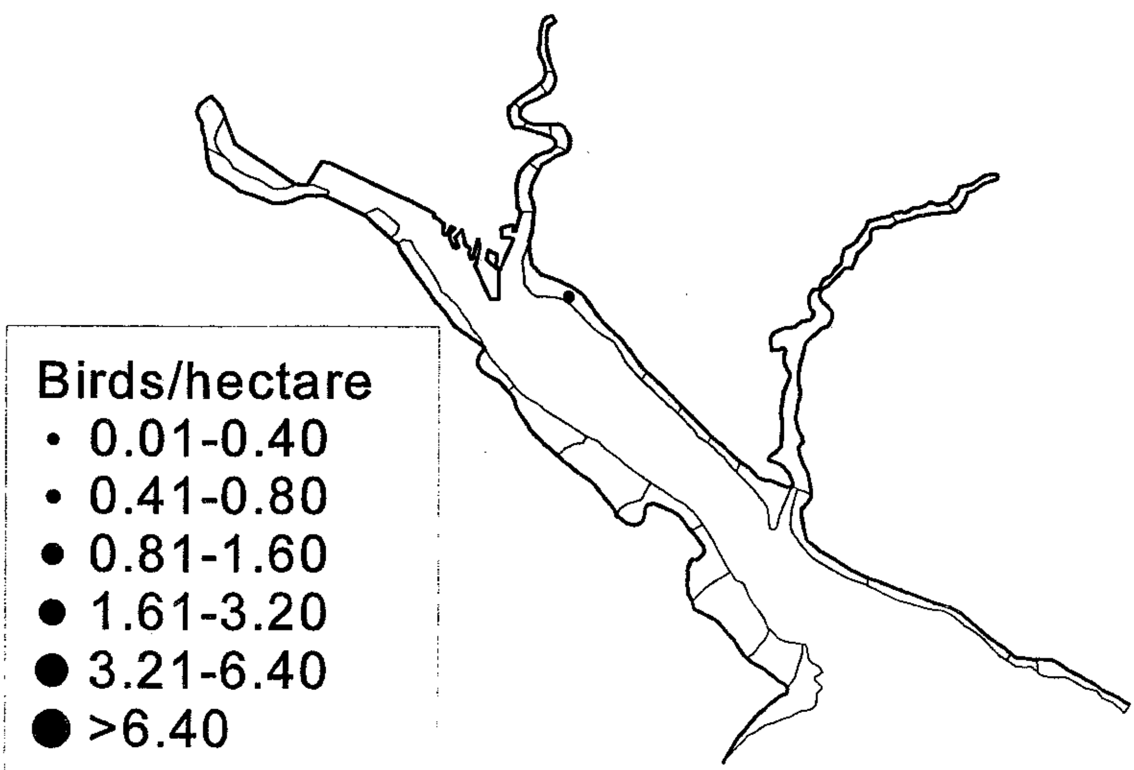
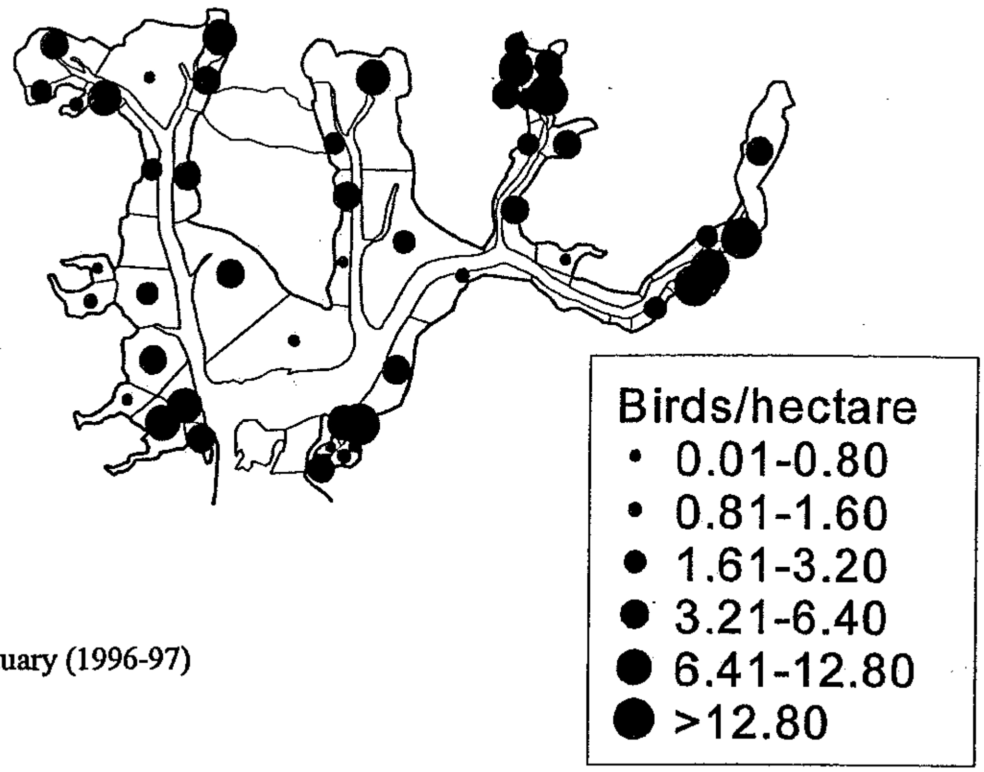


Figure 7.1.xii The distribution of Knot on Pagham Harbour and Southampton Water (based on WeBS Low Tide Counts).

Chichester Harbour (1996-97)



Stour Estuary (1996-97)

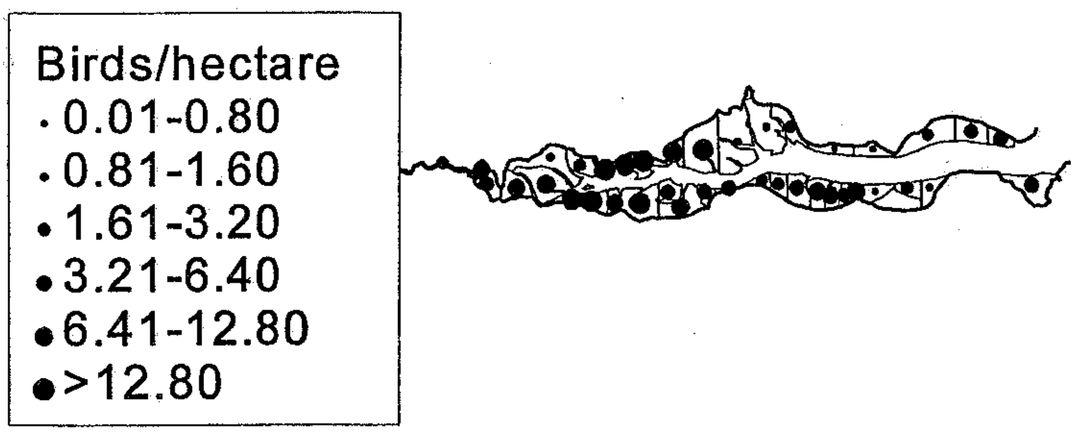
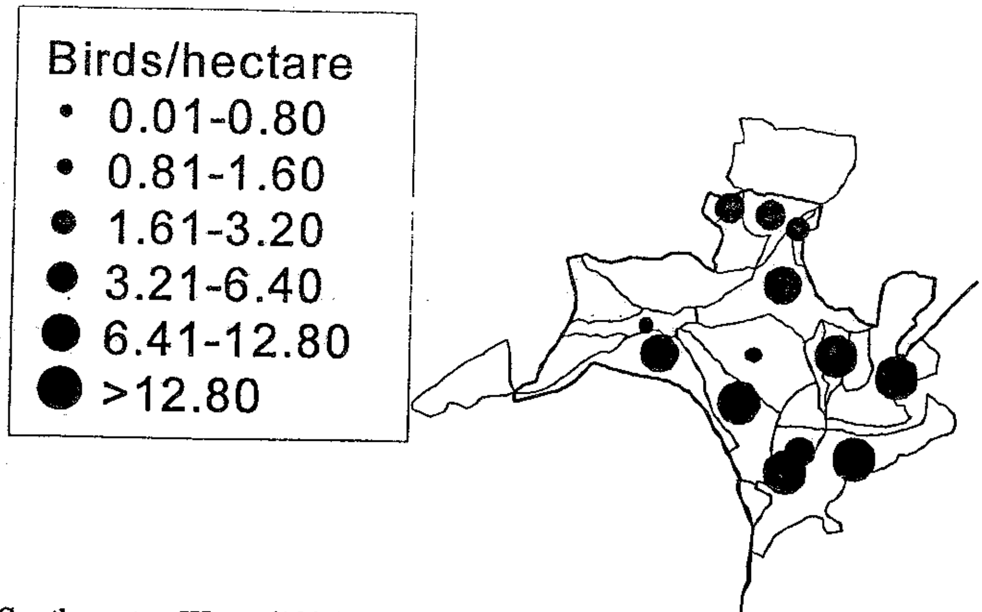


Figure 7.1.xiii The distribution of Dunlin on Chichester Harbour and the Stour Estuary (based on WeBS Low Tide Counts).

Pagham Harbour (1996-97)



Southampton Water (1996-97)

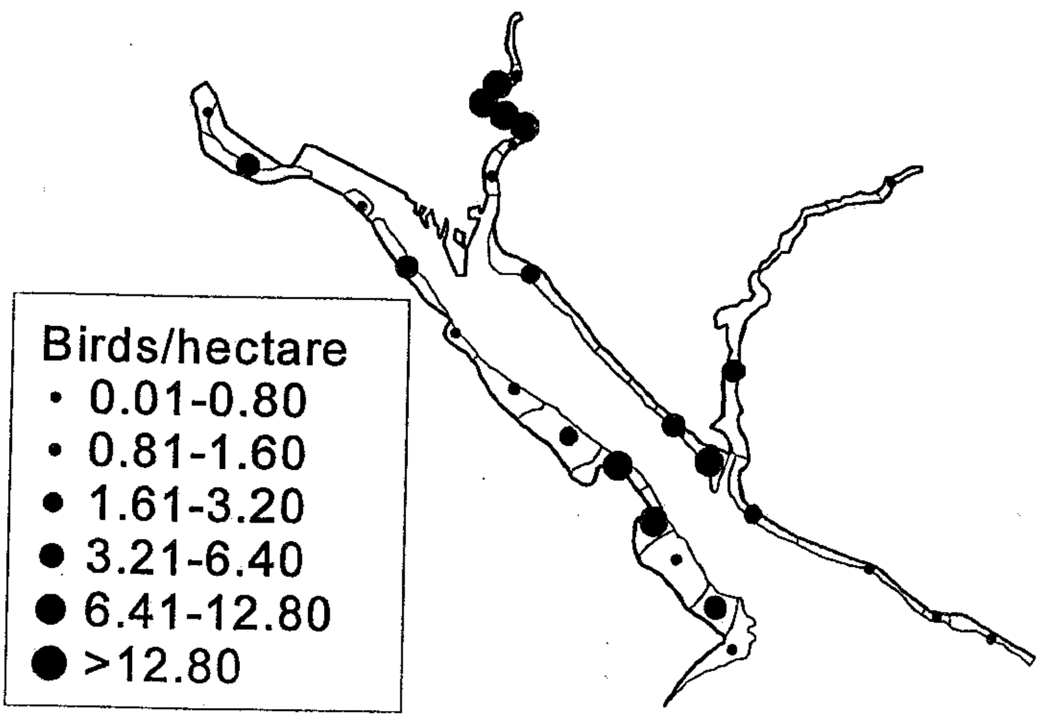
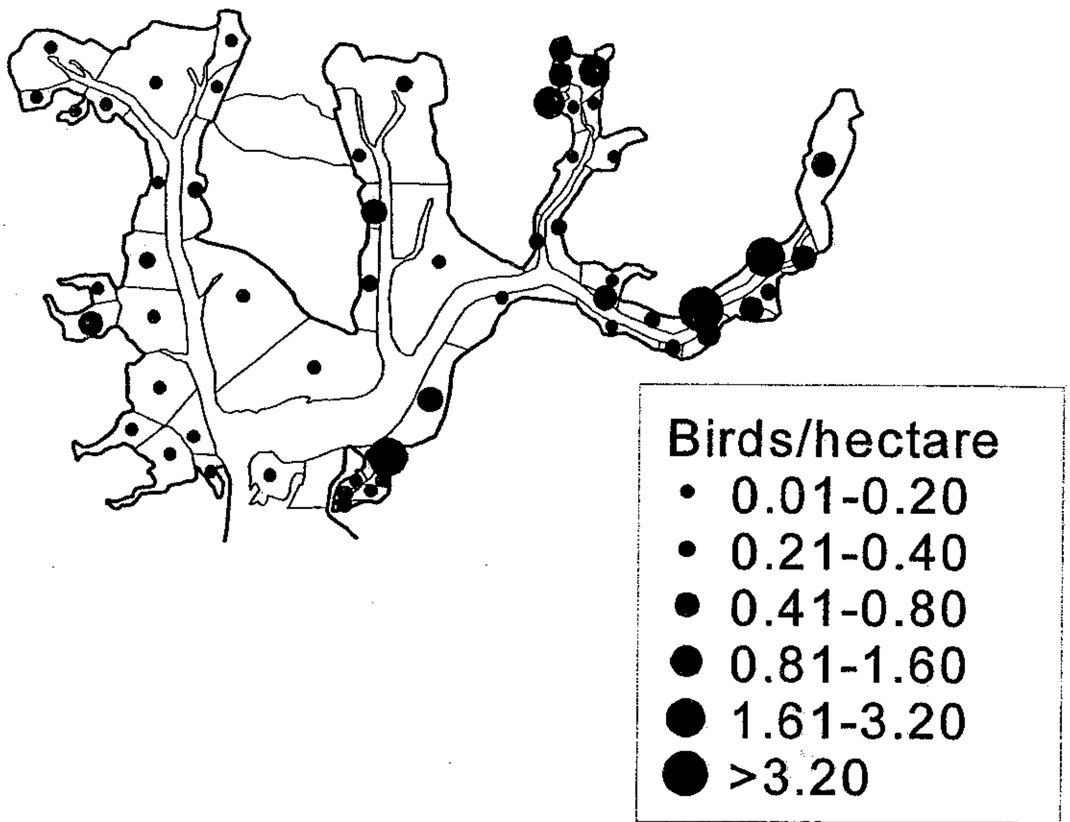


Figure 7.1.xiv The distribution of Dunlin on Pagham Harbour and Southampton Water (based on WeBS Low Tide Counts).

Chichester Harbour (1996-97)



Stour Estuary (1996-97)

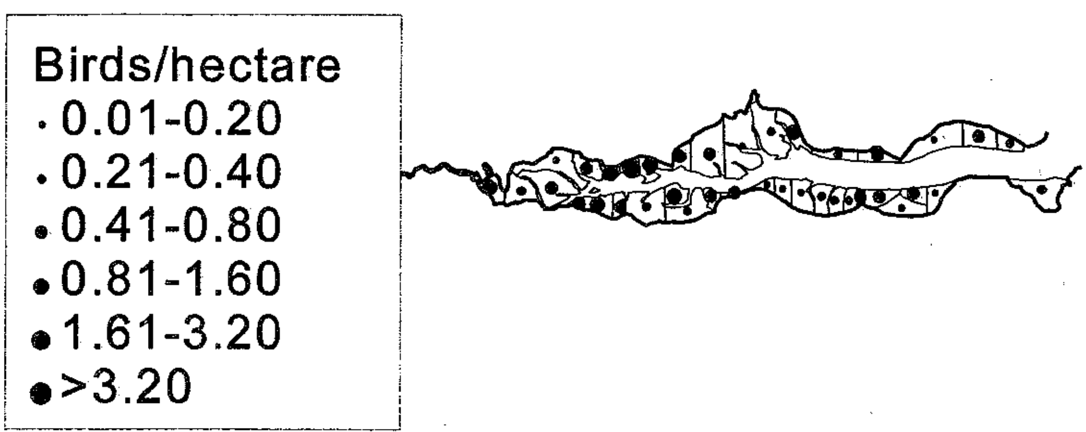
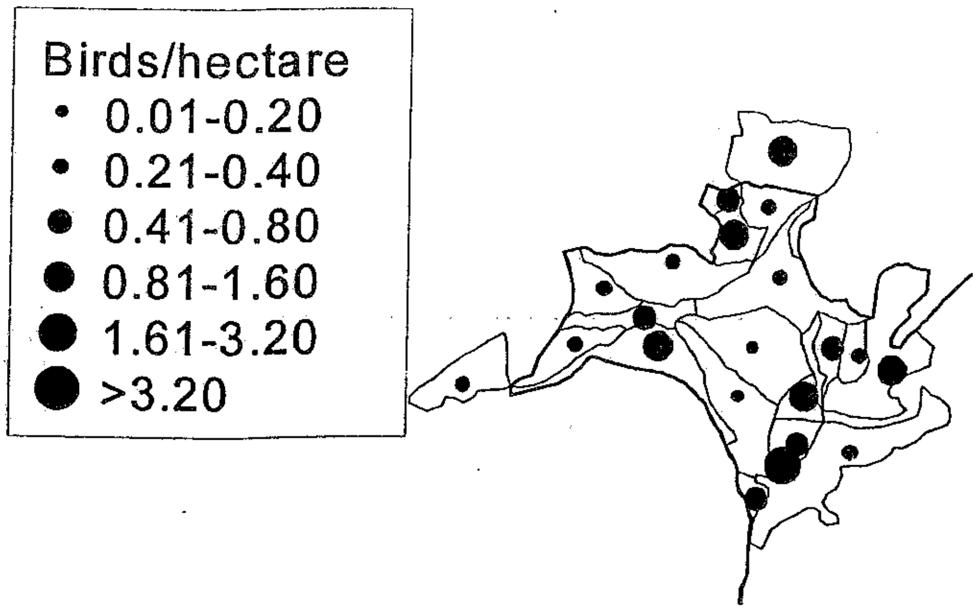


Figure 7.1.xv The distribution of Curlew on Chichester Harbour and the Stour Estuary (based on WeBS Low Tide Counts).

Pagham Harbour (1996-97)



Southampton Water (1996-97)

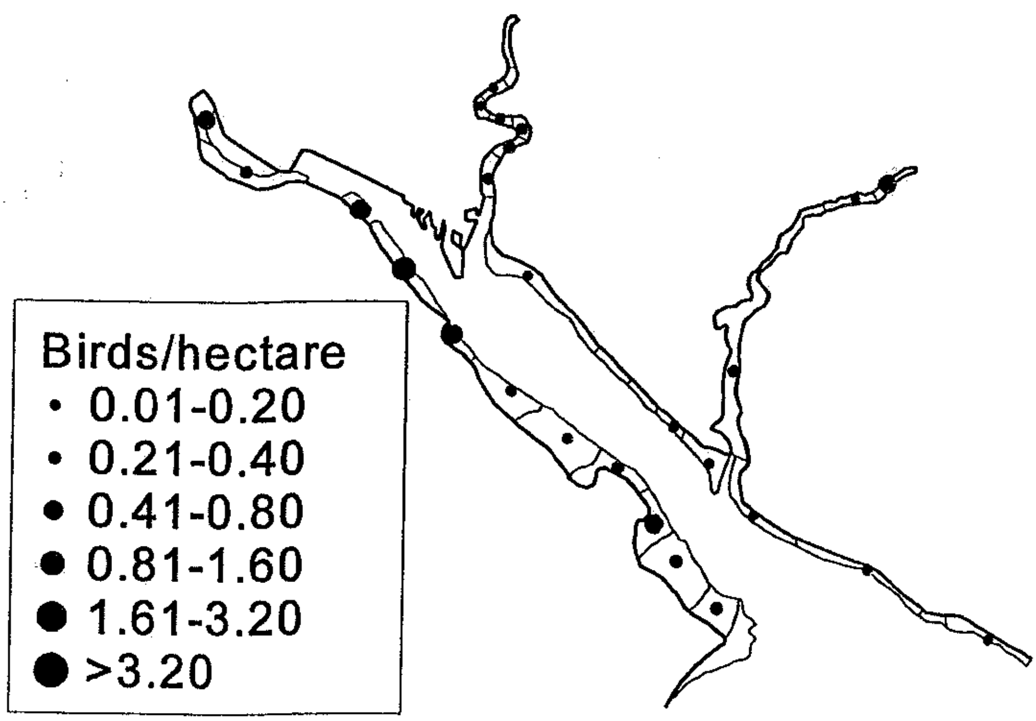
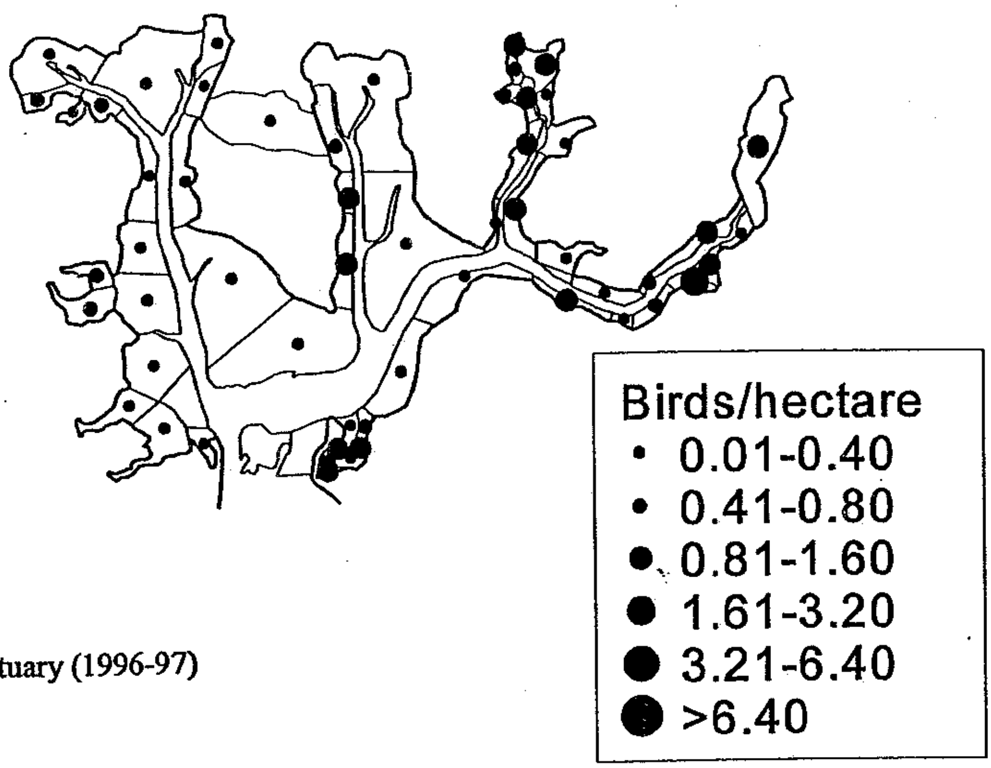


Figure 7.1.xvi The distribution of Curlew on Pagham Harbour and Southampton Water (based on WeBS Low Tide Counts).

Chichester Harbour (1996-97)



Stour Estuary (1996-97)

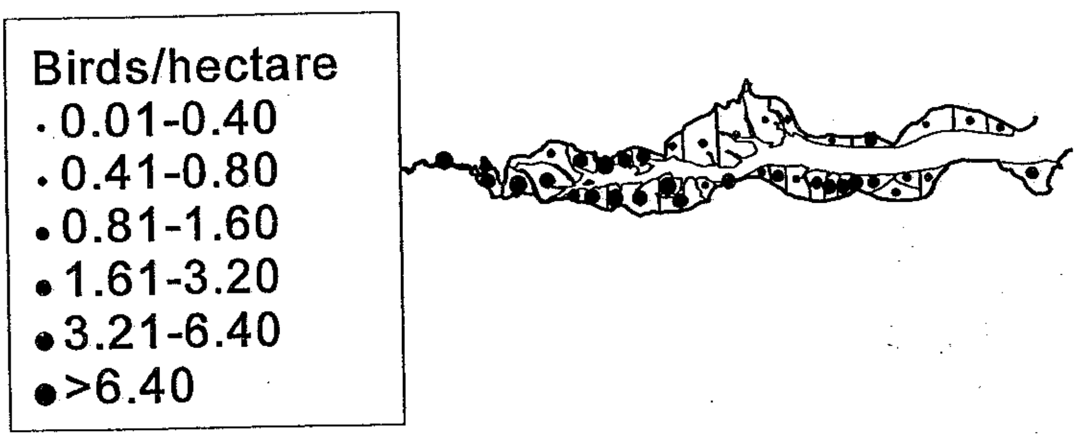
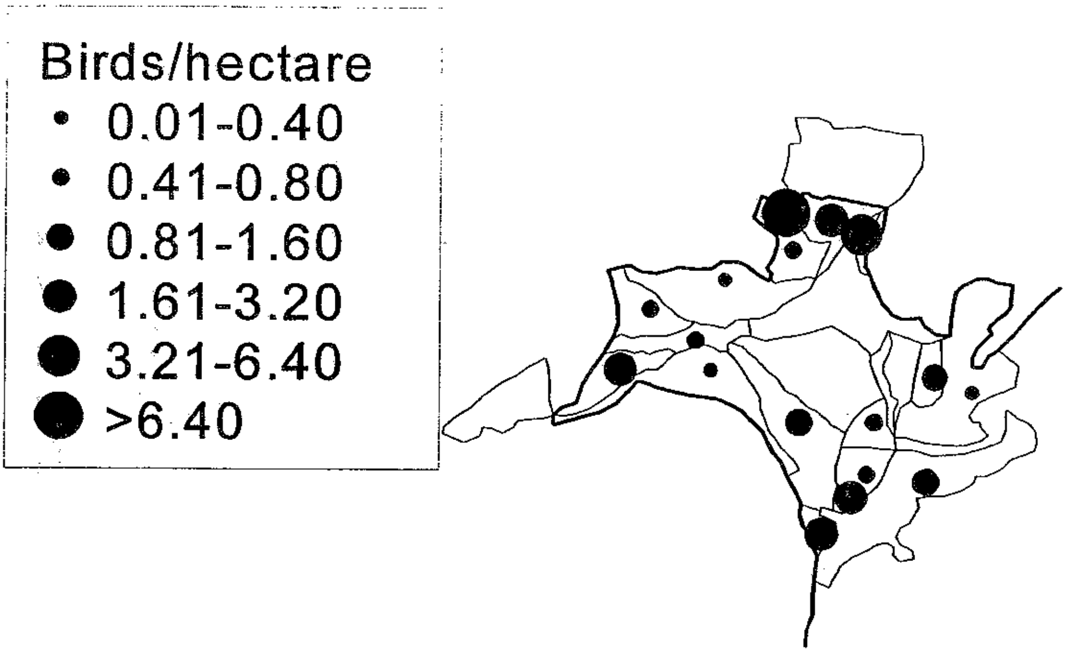


Figure 7.1.xvii The distribution of Redshank on Chichester Harbour and the Stour Estuary (based on WeBS Low Tide Counts).

Pagham Harbour (1996-97)



Southampton Water (1996-97)

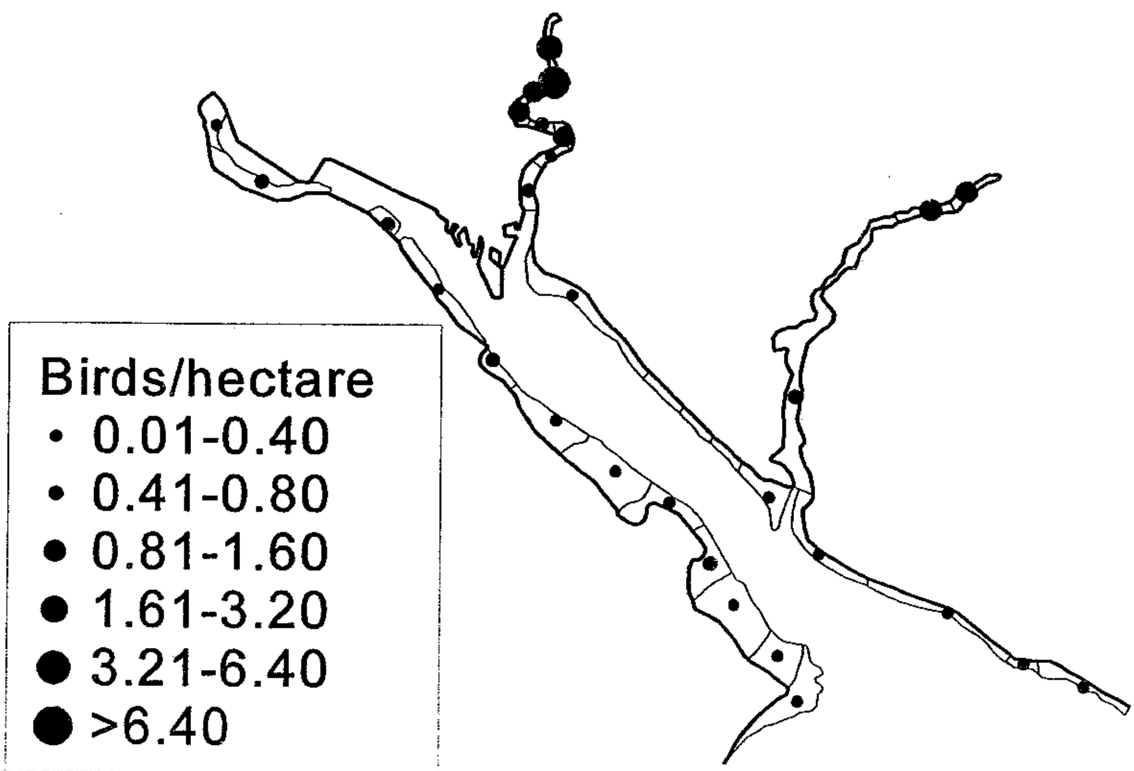
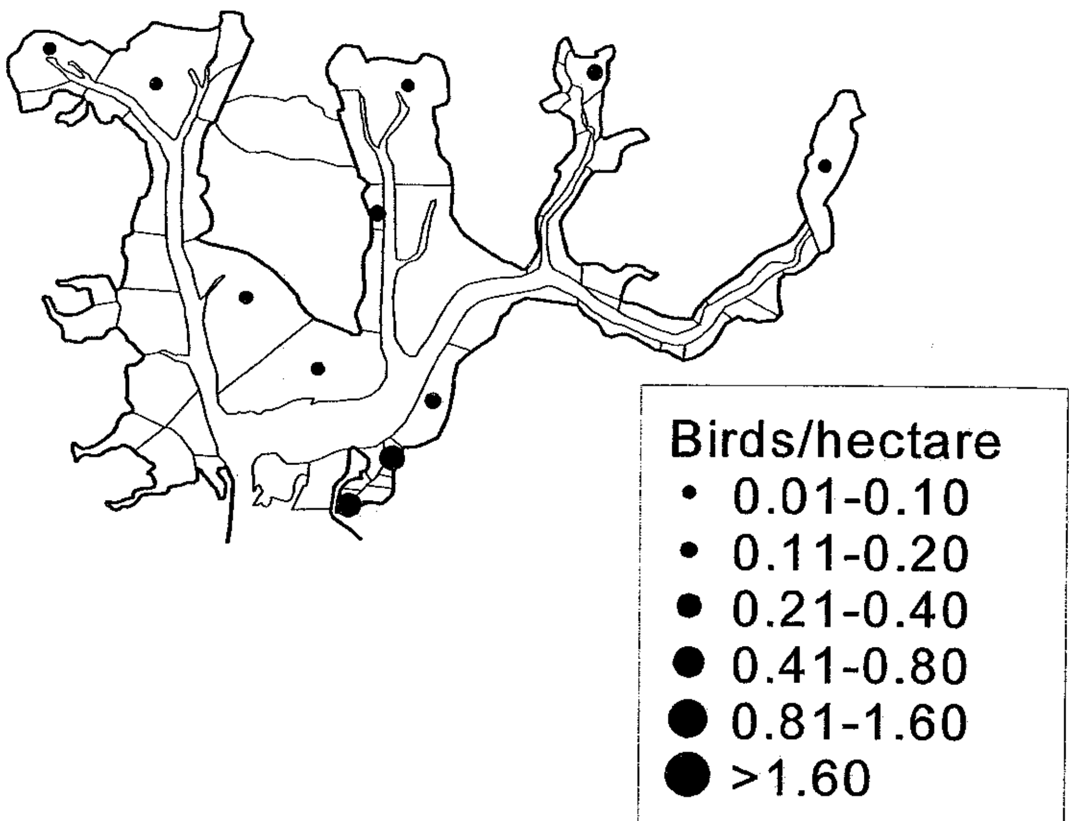


Figure 7.1.xviii The distribution of Redshank on Pagham Harbour and Southampton Water (based on WeBS Low Tide Counts).

Chichester Harbour (1996-97)



Stour Estuary (1996-97)

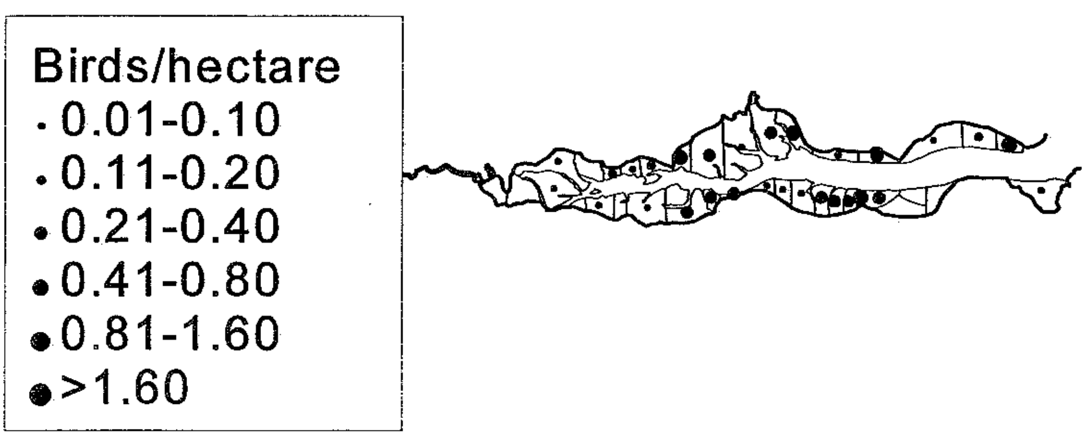
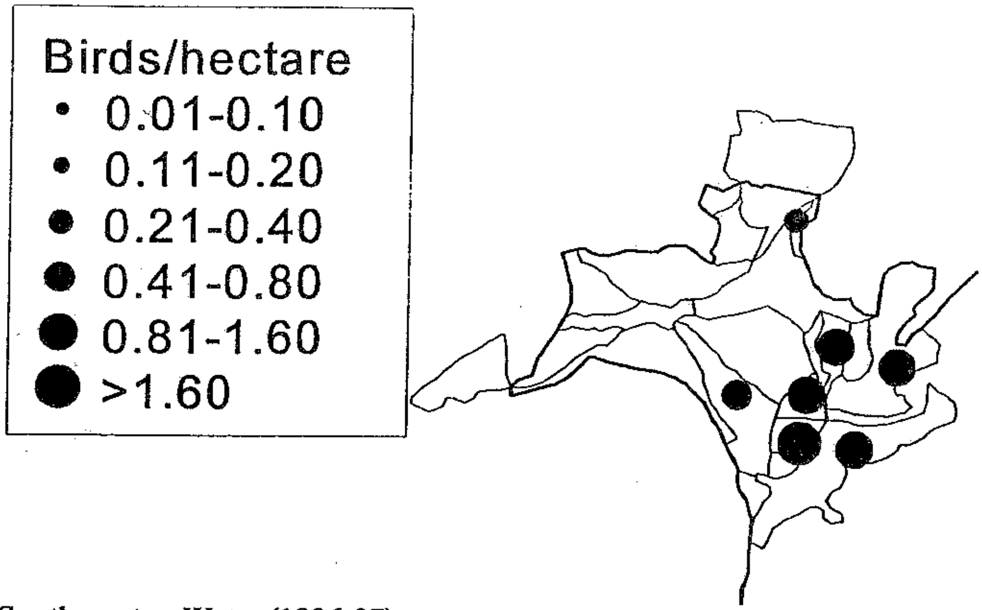


Figure 7.1.xix The distribution of Turnstone on Chichester Harbour and the Stour Estuary (based on WeBS Low Tide Counts).

Pagham Harbour (1996-97)



Southampton Water (1996-97)

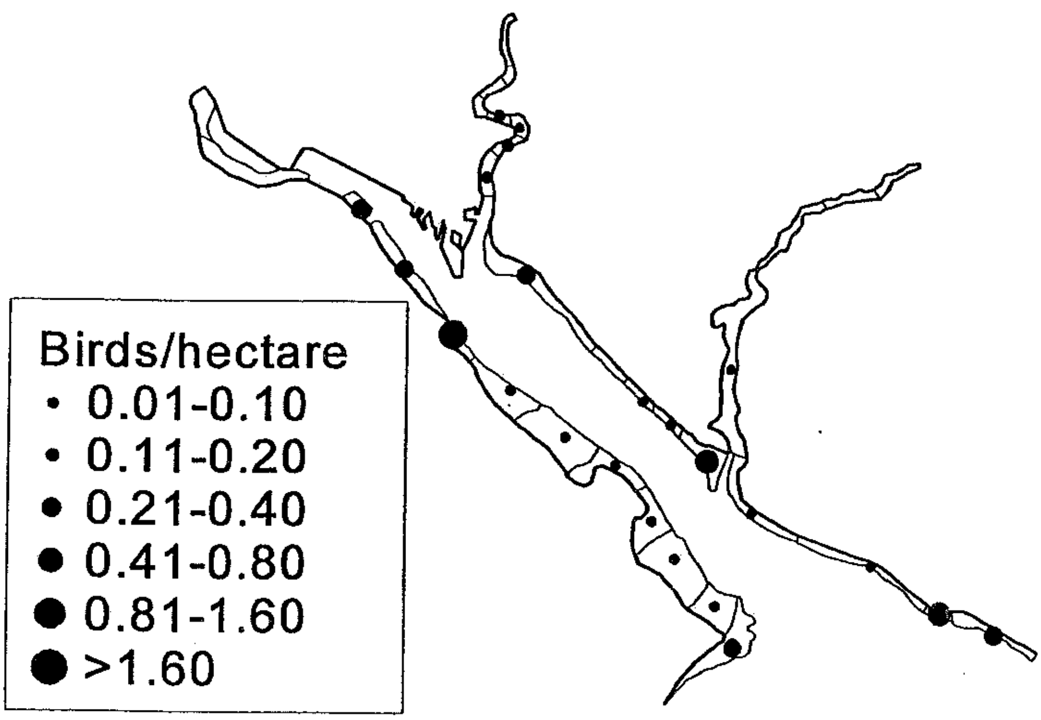


Figure 7.1.xx The distribution of Turnstone on Pagham Harbour and Southampton Water (based on WeBS Low Tide Counts).

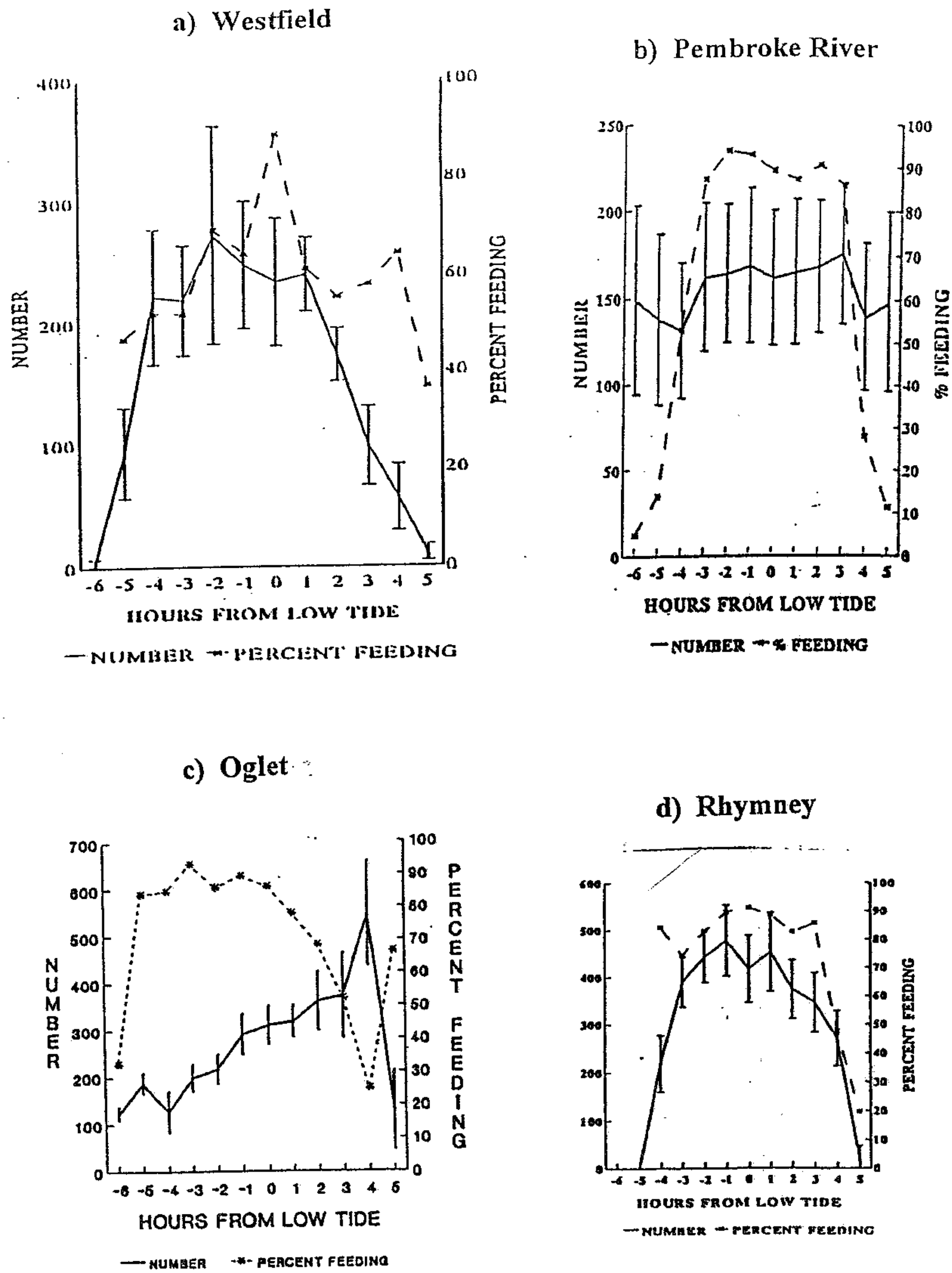


Figure 7.2.1 Through the tidal cycle distributions of feeding waterfowl (Shelduck).

a) Evans *et al.* 1997 - Morecambe Bay;
b) Armitage *et al.* 1997 - Milford Haven;
c) Clark *et al.* 1990 - Mersey; and
d) Burton *et al.* 1997 - Cardiff Bay.

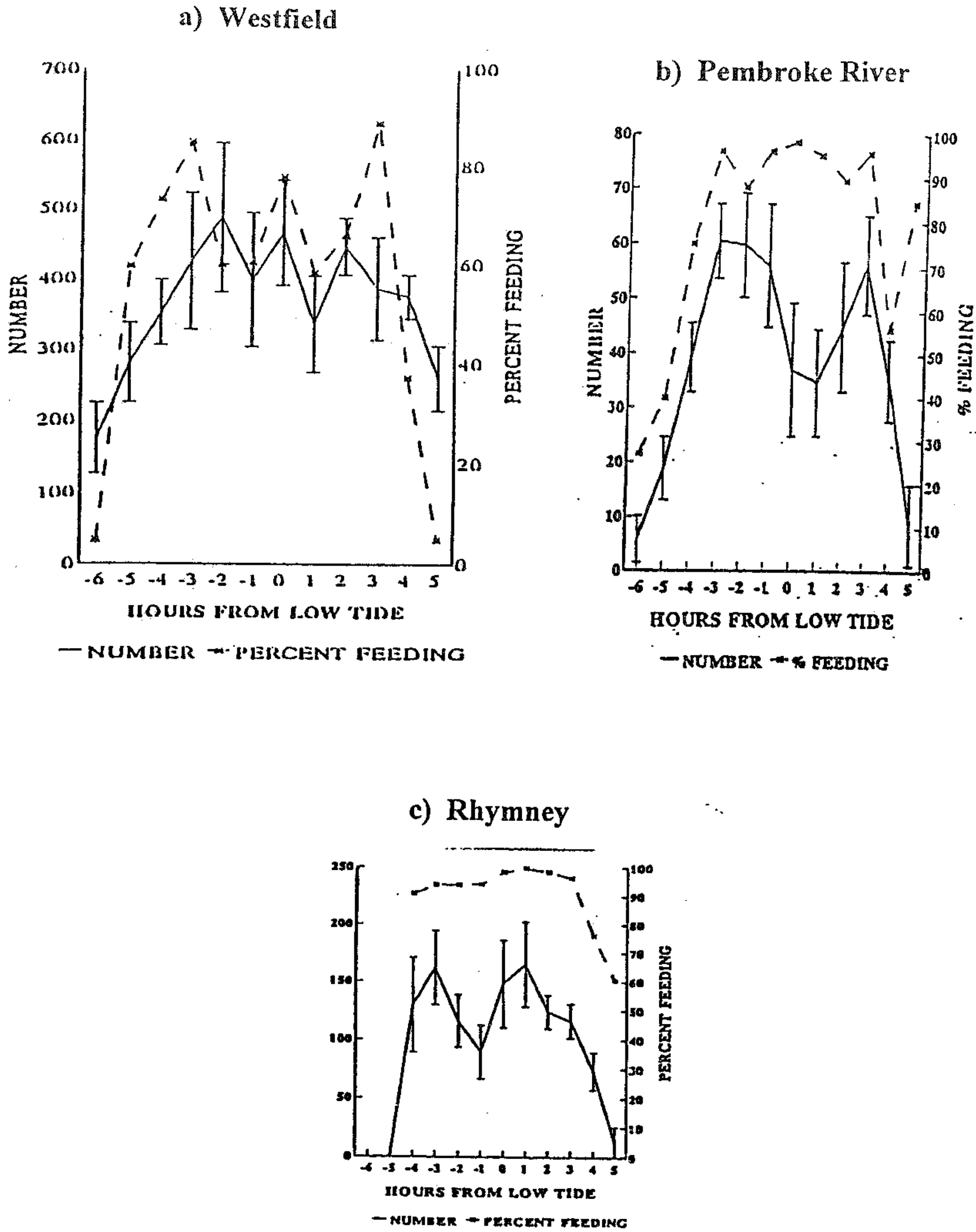


Figure 7.2.1 (Cont.) Through the tidal cycle distributions of feeding waterfowl (Oystercatcher).

a) Evans *et al.* 1997 - Morecambe Bay;
b) Armitage *et al.* 1997 - Milford Haven; and
c) Burton *et al.* 1997 - Cardiff Bay.

a) Rhymney

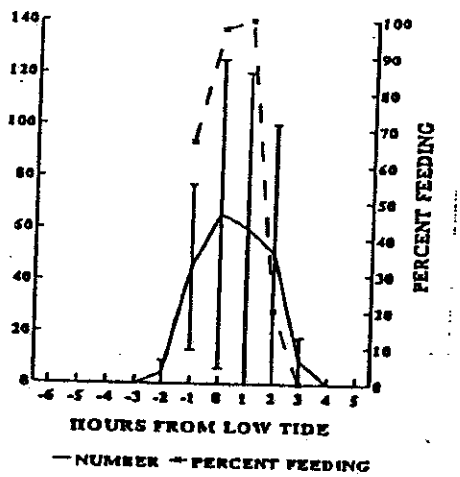


Figure 7.2.1 (Cont.) Through the tidal cycle distributions of feeding waterfowl (Knot).

a) Burton *et al.* 1997 - Cardiff Bay.

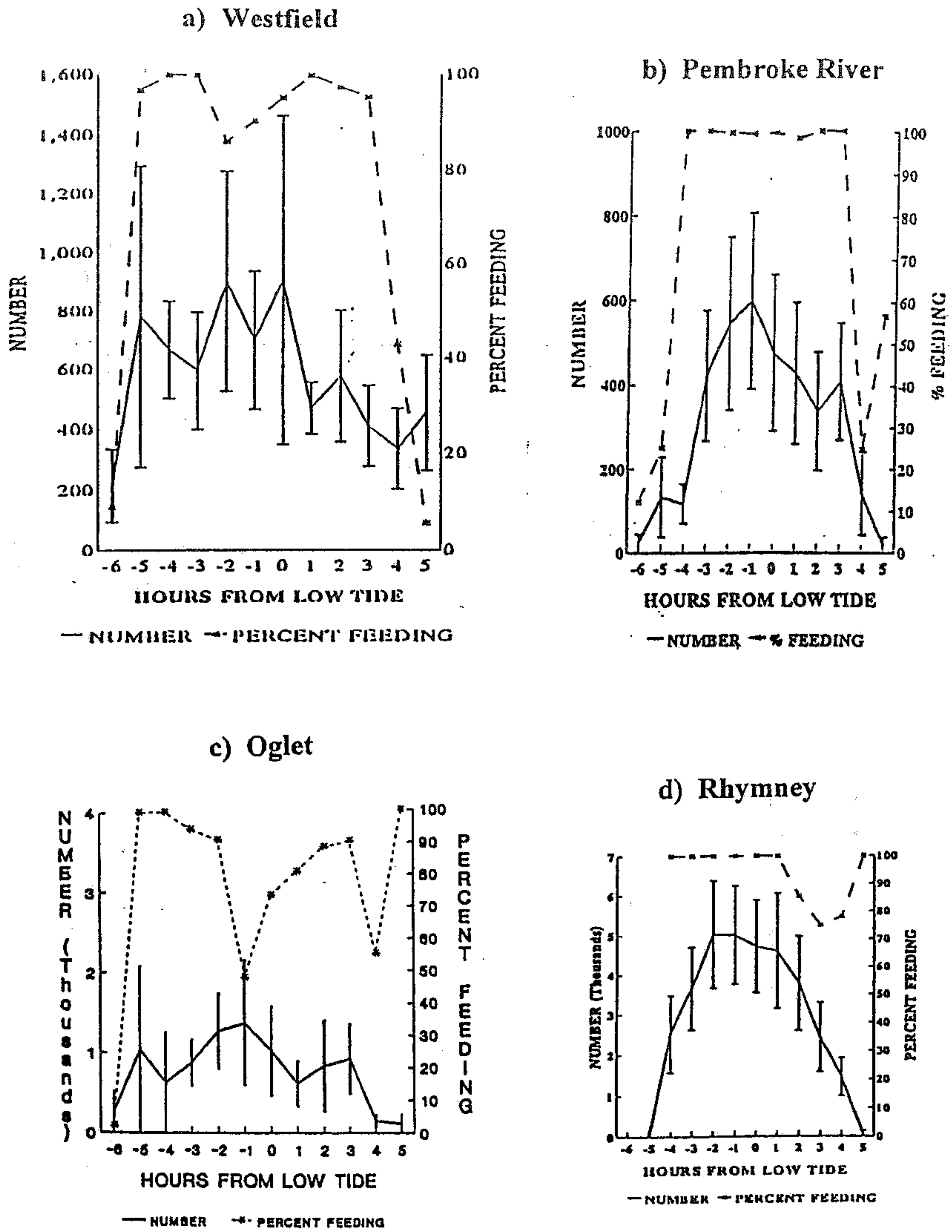


Figure 7.2.1 (Cont.) Through the tidal cycle distributions of feeding waterfowl (Dunlin).

a) Evans *et al.* 1997 - Morecambe Bay;
b) Armitage *et al.* 1997 - Milford Haven;
c) Clark *et al.* 1990 - Mersey; and
d) Burton *et al.* 1997 - Cardiff Bay.

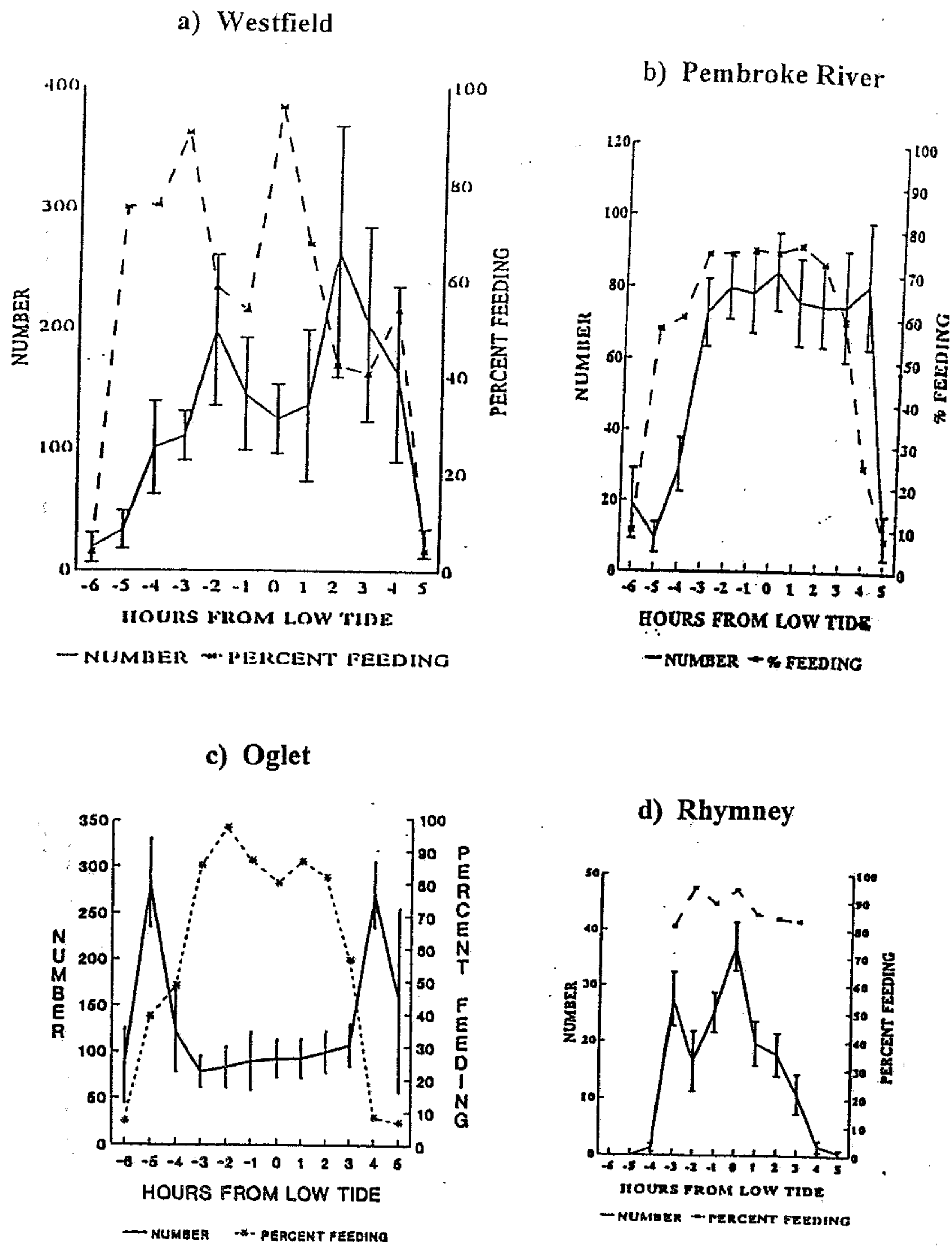


Figure 7.2.1 (Cont.) Through the tidal cycle distributions of feeding waterfowl (Curlew).

a) Evans *et al*. 1997 - Morecambe Bay;
b) Armitage *et al*. 1997 - Milford Haven;
c) Evans *et al*. 1990 - Mersey; and
d) Burton *et al*. 1997 - Cardiff Bay.

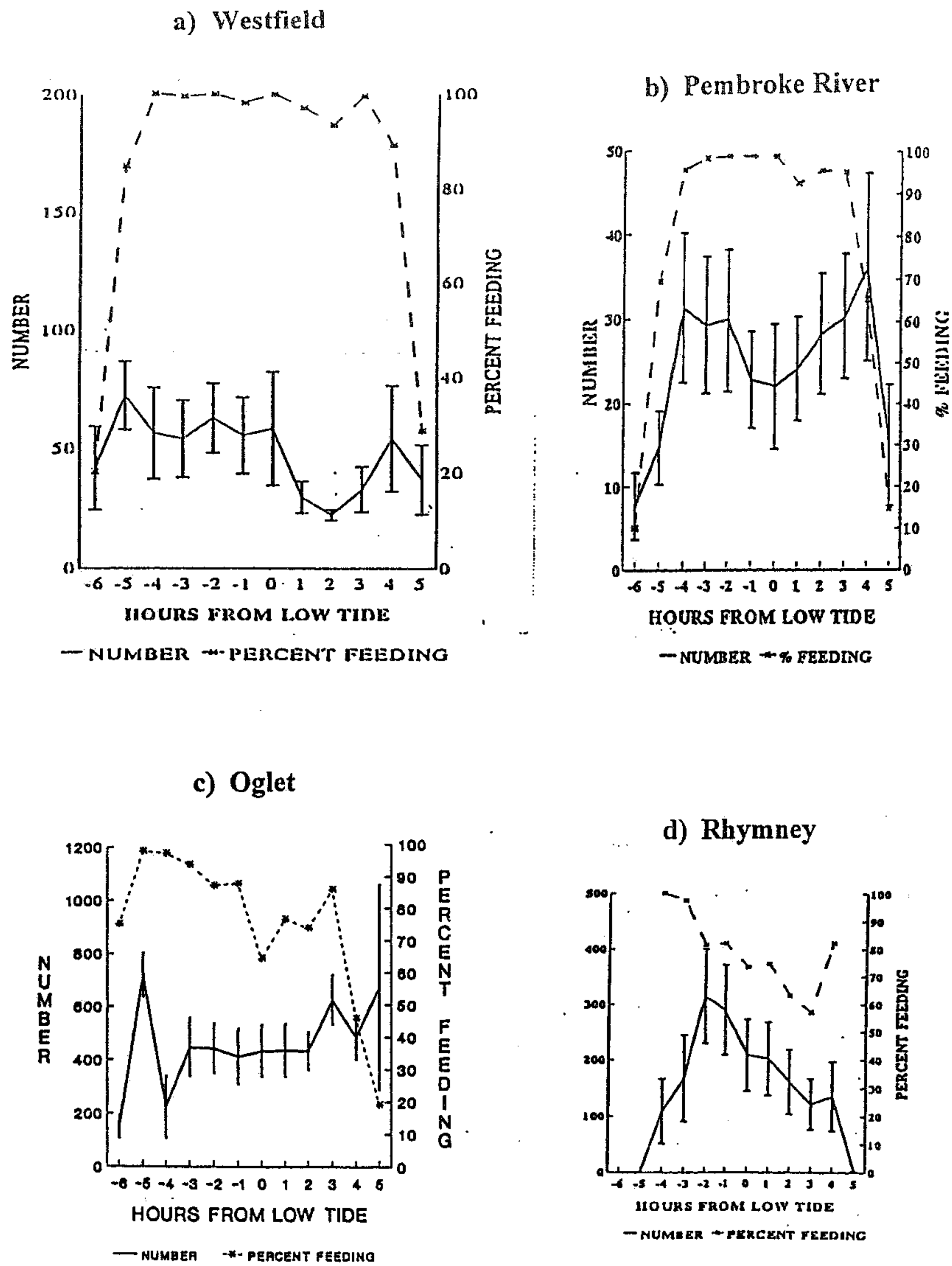
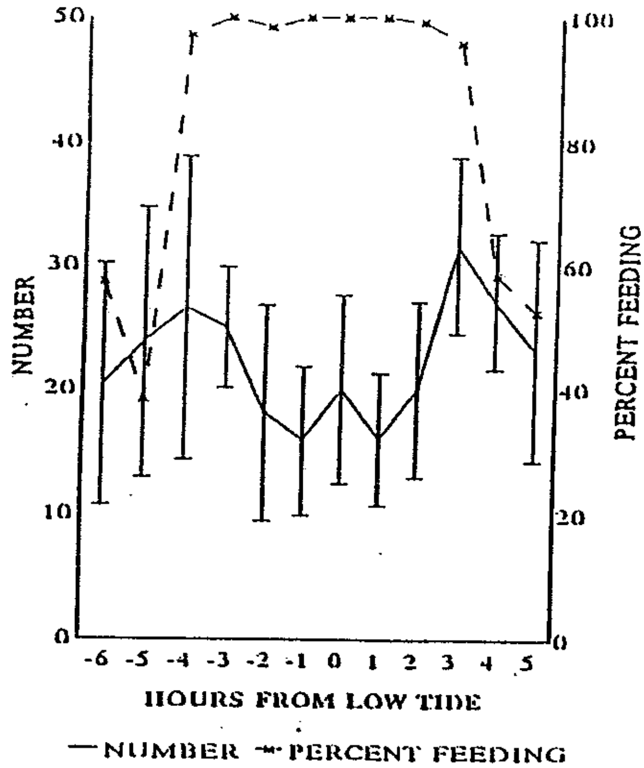


Figure 7.2.1 (Cont.) Through the tidal cycle distributions of feeding waterfowl (Redshank).

a) Evans *et al*. 1997 - Morecambe Bay;
b) Armitage *et al*. 1997 - Milford Haven;
c) Evans *et al*. 1990 - Mersey; and
d) Burton *et al*. 1997 - Cardiff Bay.

a) Walney Foreshore



b) Orchard Ledges

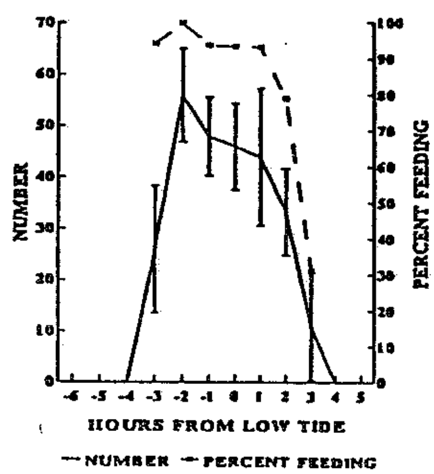


Figure 7.2.1 (Cont.) Through the tidal cycle distributions of feeding waterfowl (Turnstone).

a) Evans *et al.* 1997 - Morecambe Bay; and
b) Burton *et al.* 1997 - Cardiff Bay.

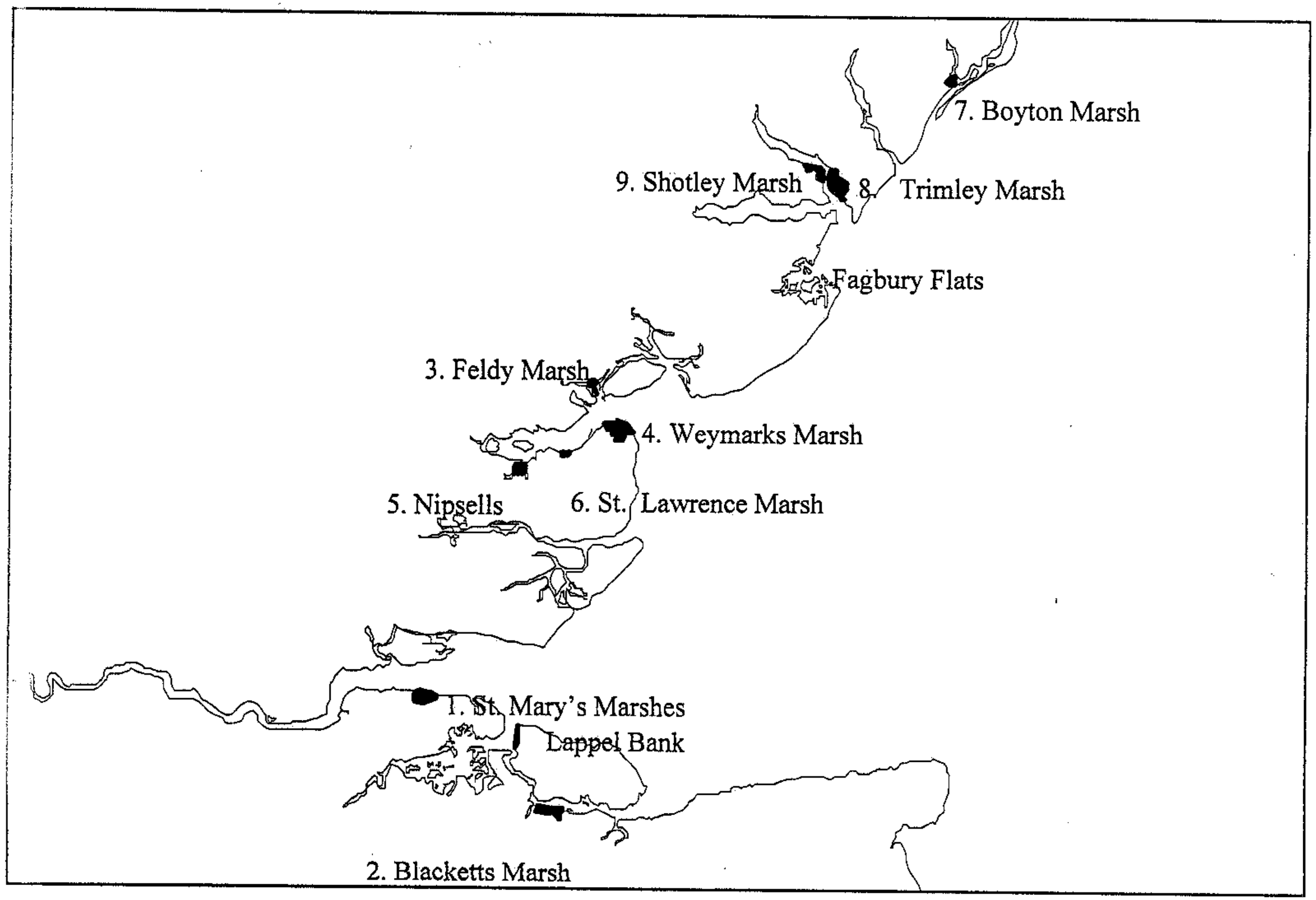
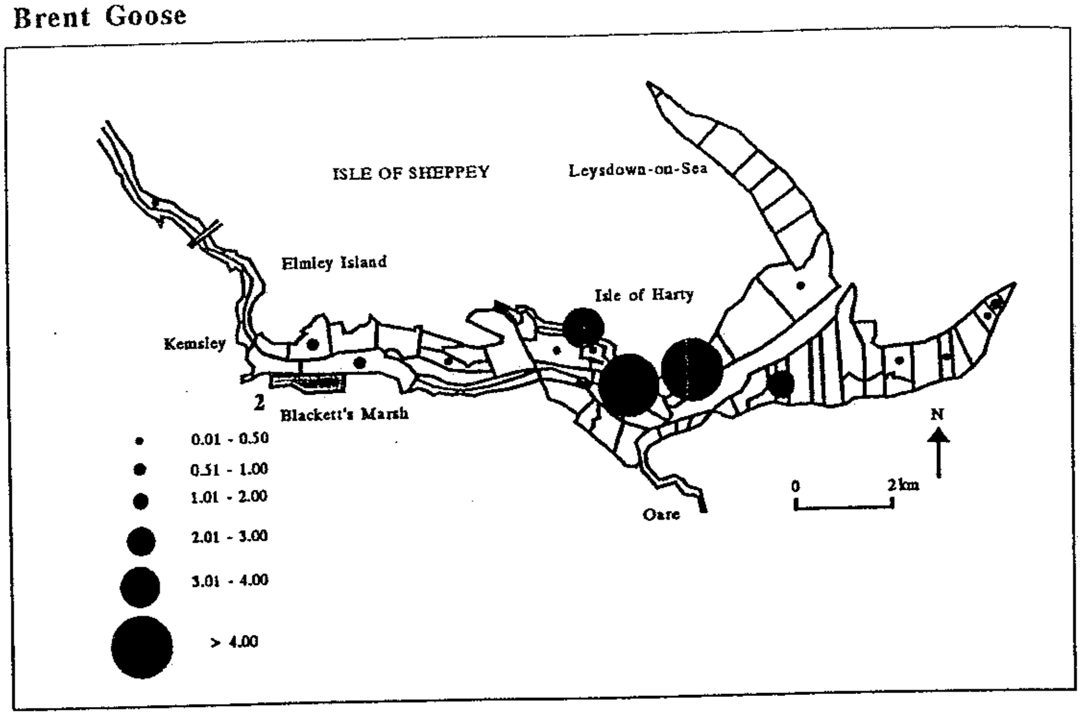


Figure 8.2.1. Map of Southeast England showing the locations of Lappel Bank, Fagbury Flats and the nine proposed compensation sites.

Brent Goose



Shelduck

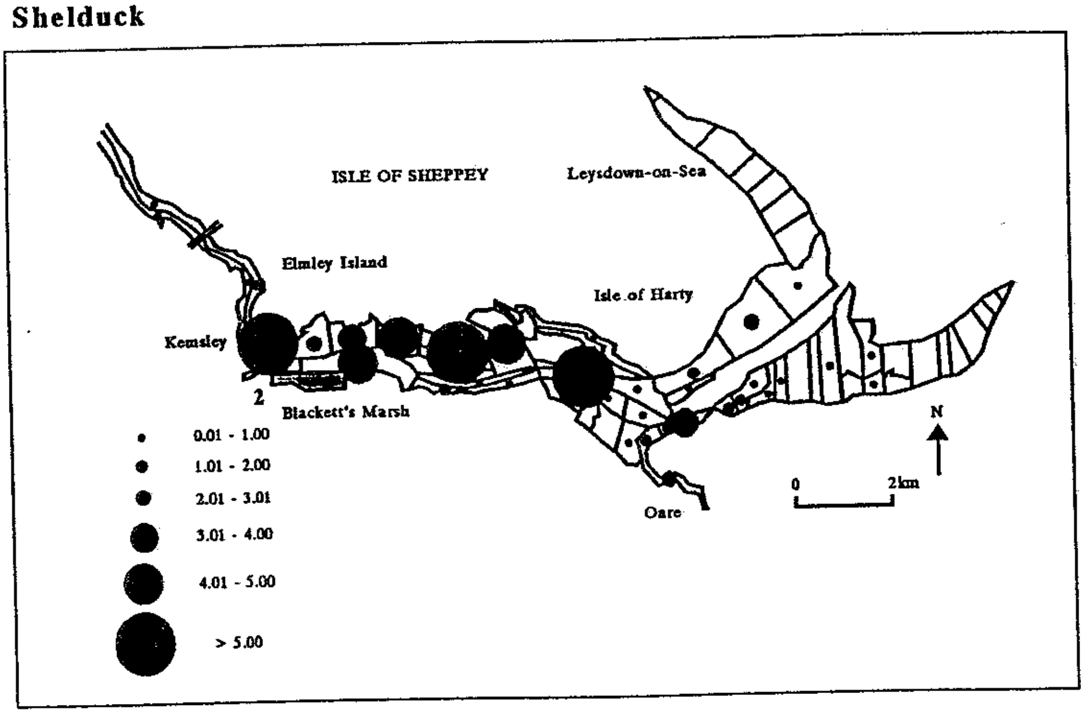
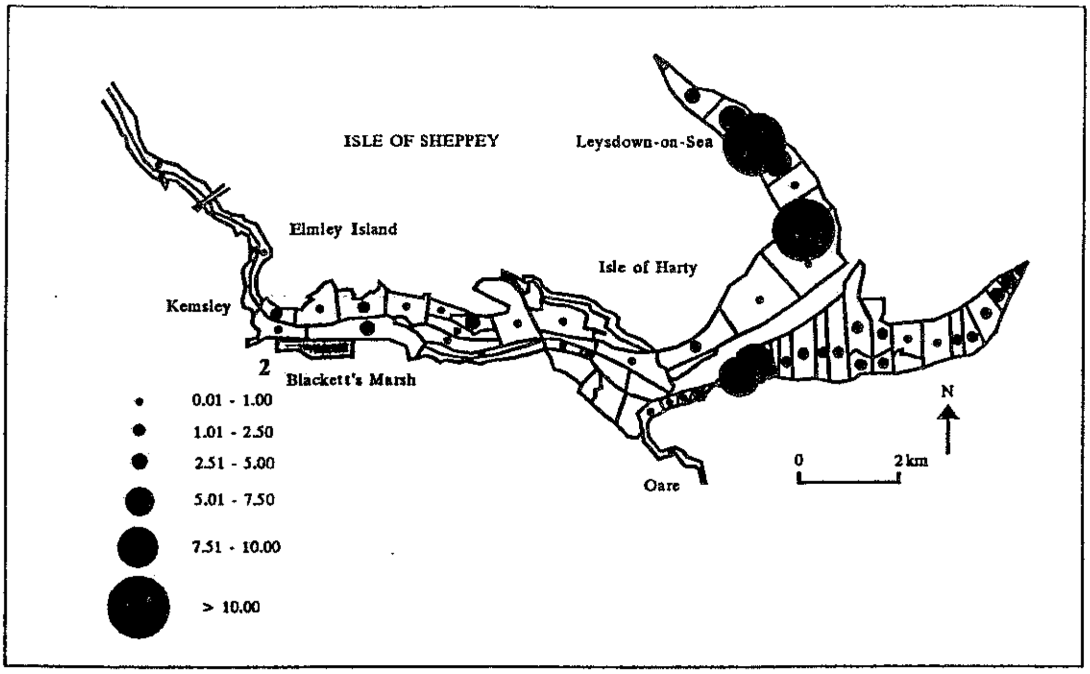


Figure 8.2.2 The mean density of Brent Geese and Shelduck on each count area during the 1992/93 Low Tide Counts on the Swale Estuary. Shaded area: possible compensation site 2, Blackett's Marsh.

Oystercatcher



Ringed Plover

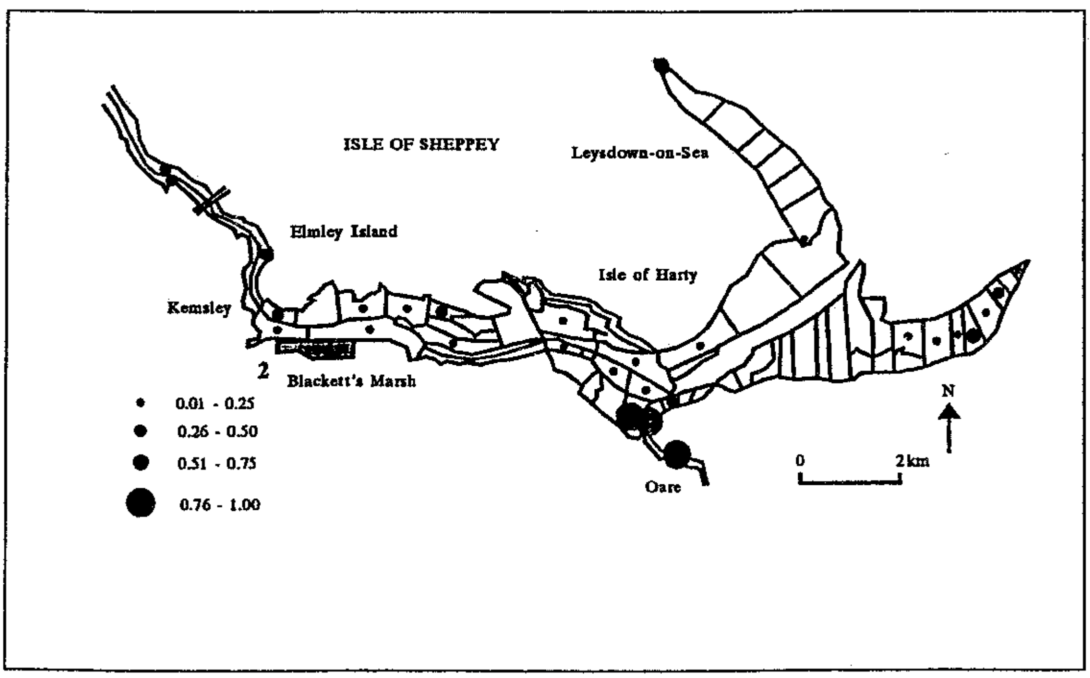
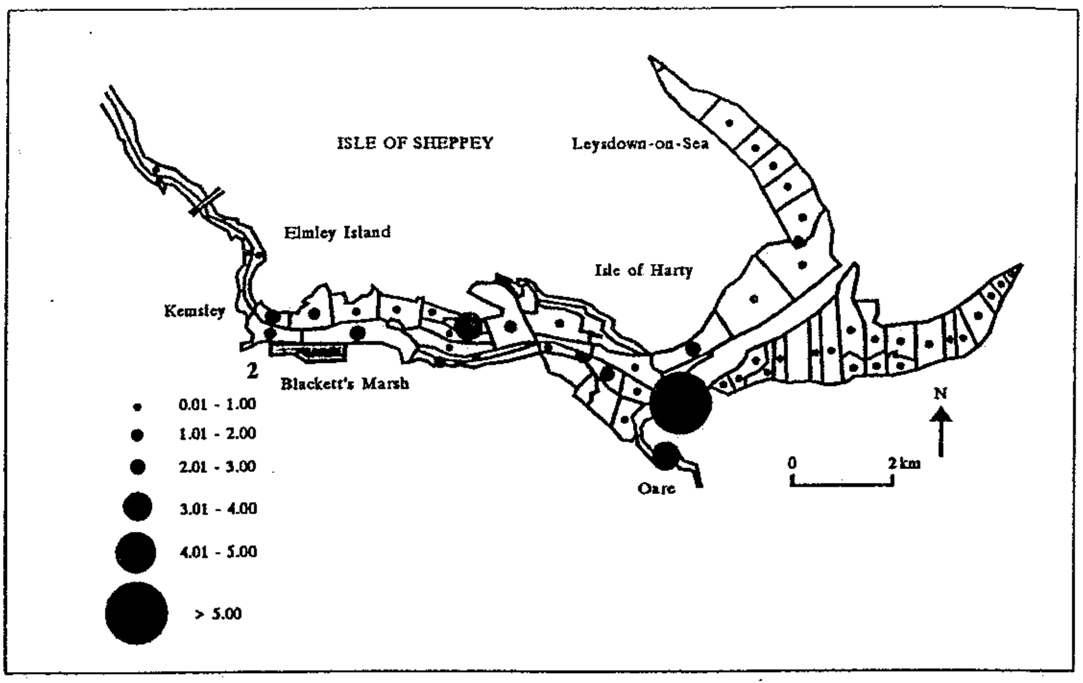


Figure 8.2.2 The mean density of Oystercatcher and Ringed Plover on each count area during the 1992/93 Low Tide Counts on the Swale Estuary. Shaded area: possible compensation site 2, Blackett's Marsh.

Grey Plover



Knot

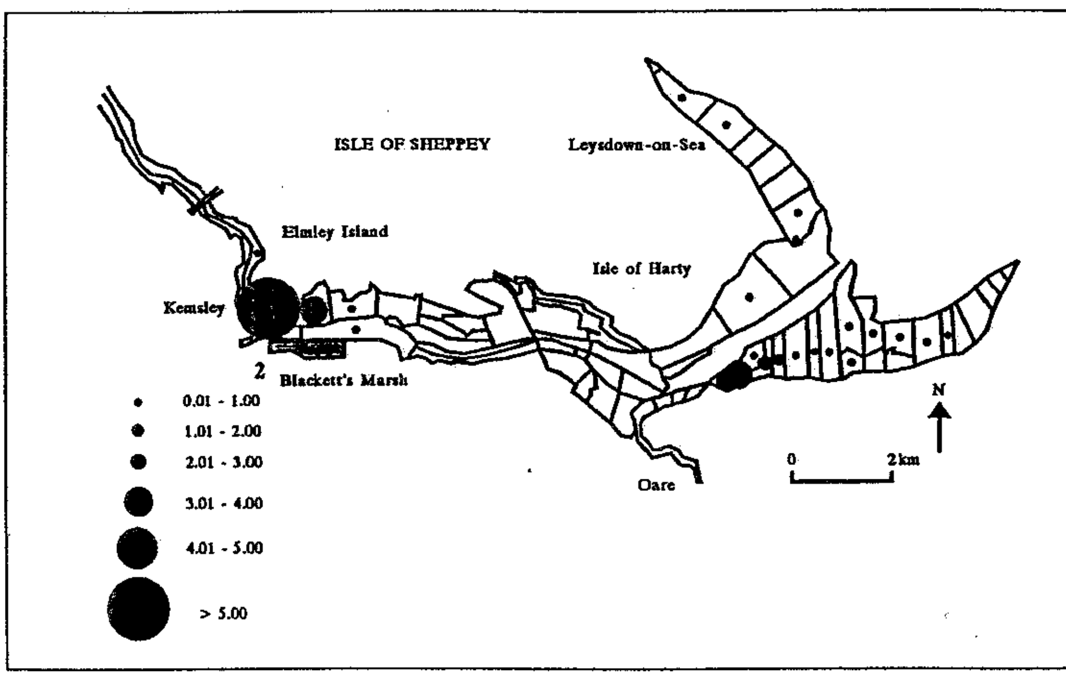
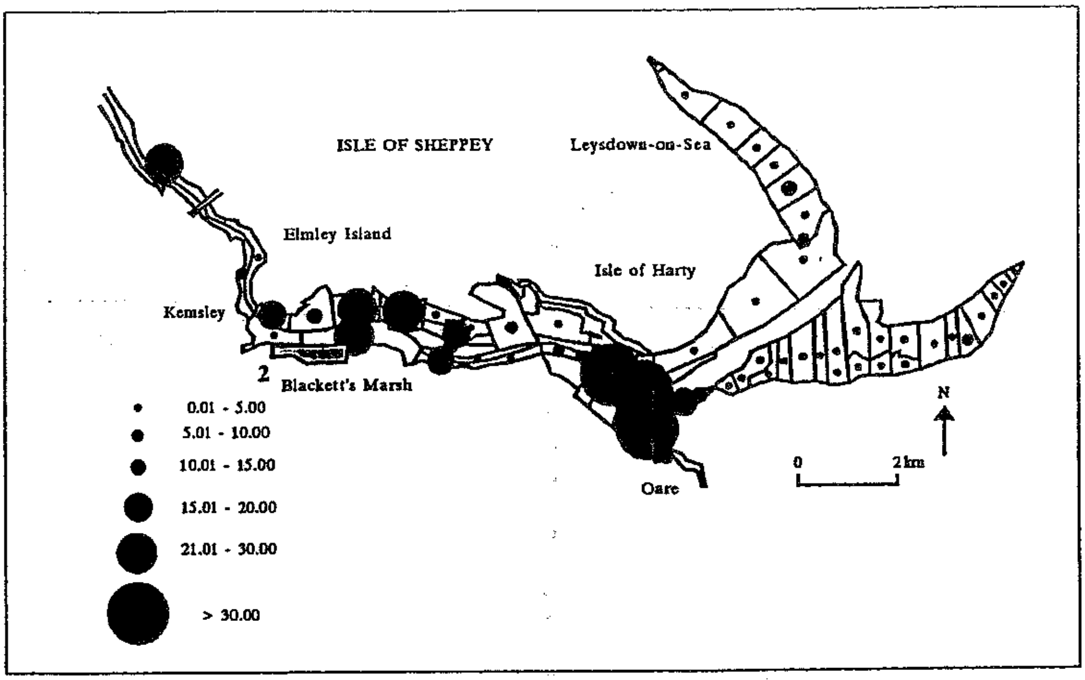


Figure 8.2.2 The mean density of Grey Plover and Knot on each count area during the 1992/93 Low Tide Counts on the Swale Estuary. Shaded area: possible compensation site 2, Blackett's Marsh.

Dunlin



Curlew

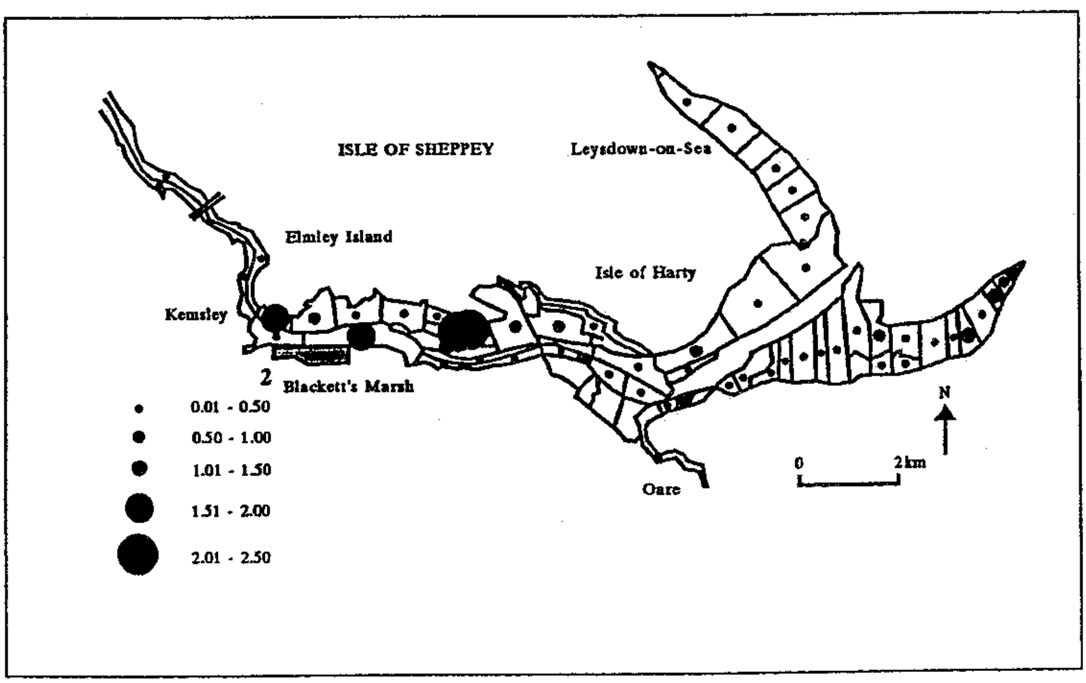
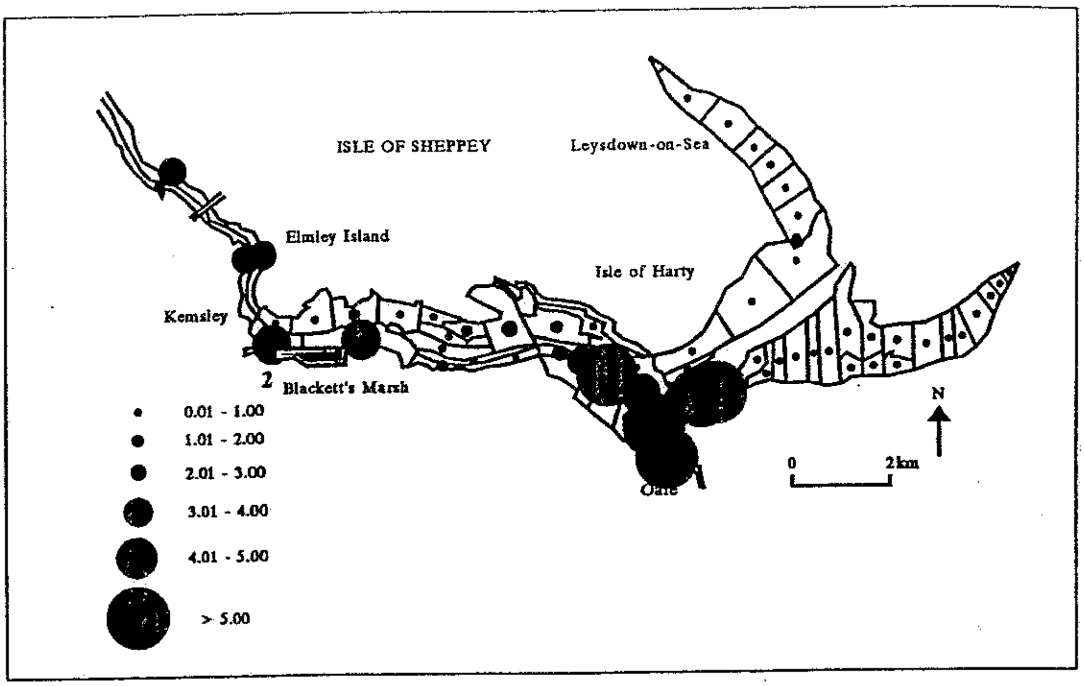


Figure 8.2.2 The mean density of Dunlin and Curlew on each count area during the 1992/93 Low Tide Counts on the Swale Estuary. Shaded area: possible compensation site 2, Blackett's Marsh.

Redshank



Turnstone

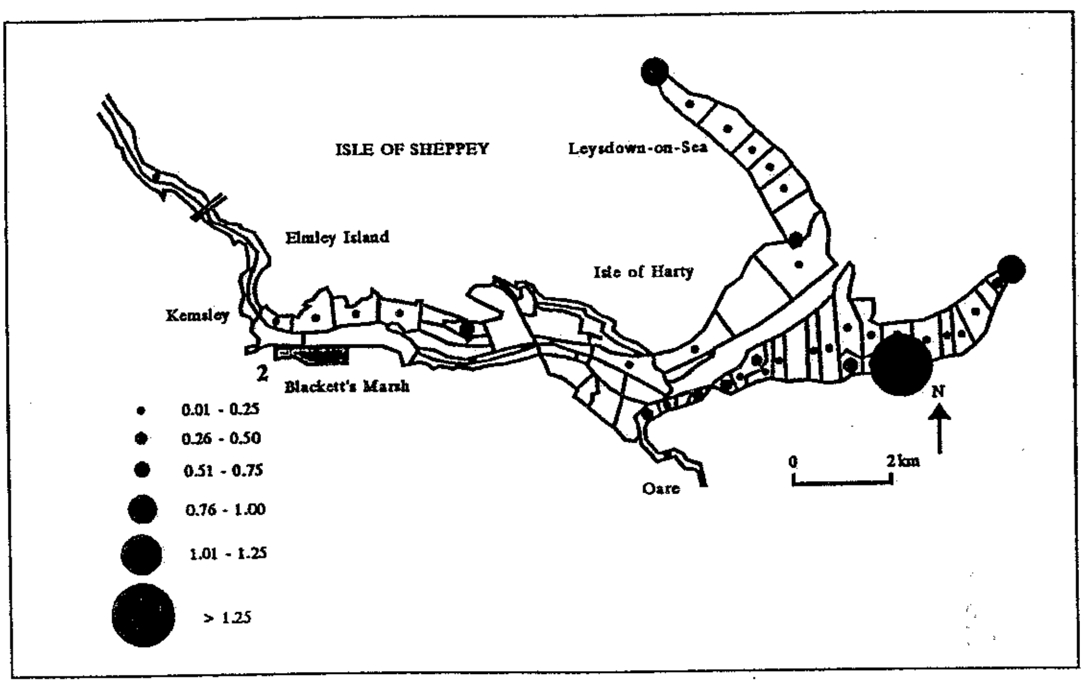
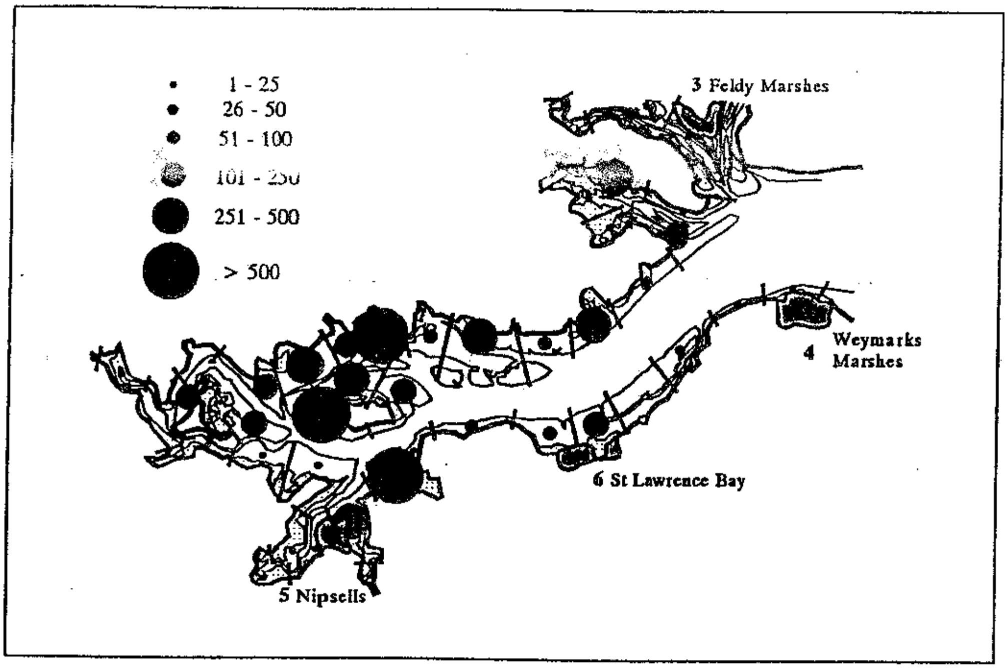


Figure 8.2.2 The mean density of Redshank and Turnstone on each count area during the 1992/93 Low Tide Counts on the Swale Estuary. Shaded area: possible compensation site 2, Blackett's Marsh.

Brent Goose



Shelduck

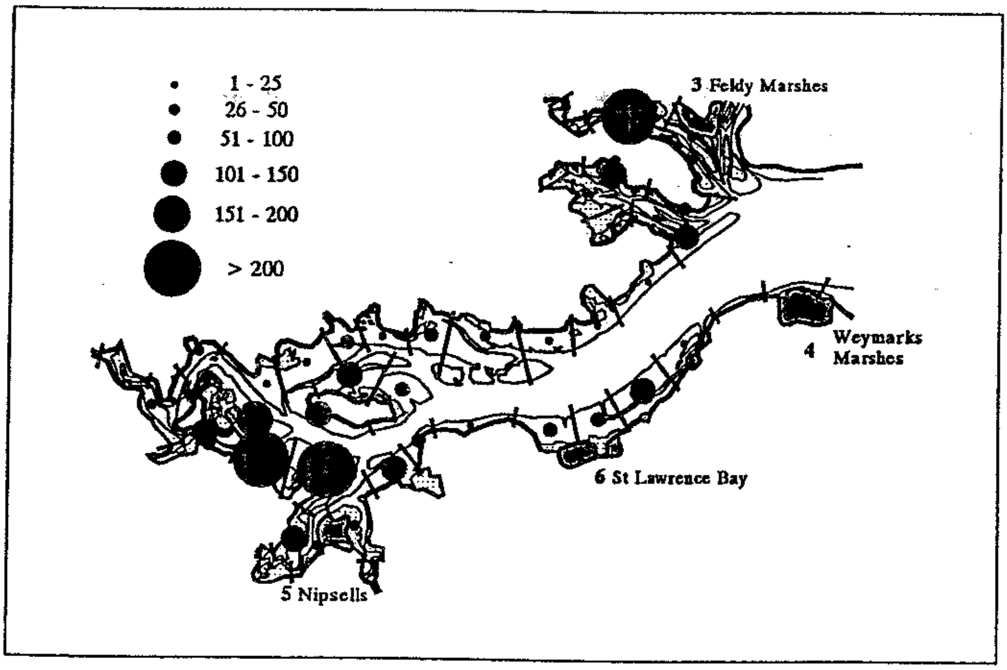
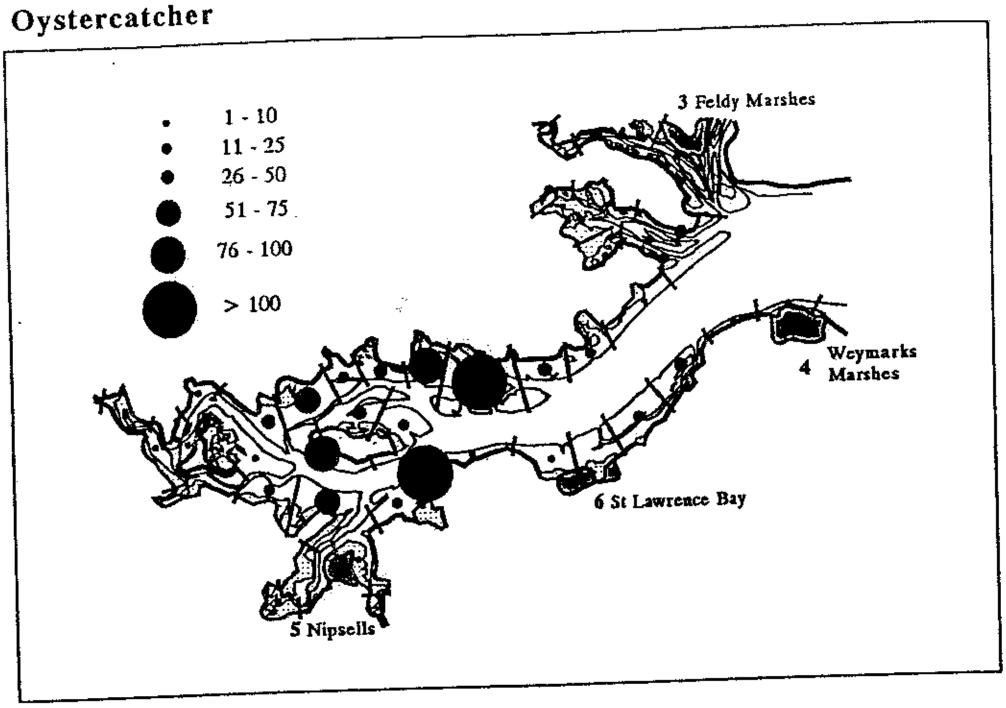


Figure 8.2.3 The average number of Brent Geese and Shelduck recorded on each count area during the 1994/95 Low Tide Counts on the Blackwater Estuary. Shaded areas: possible compensation sites 3, Feldy Marshes; 4, Weymarks Marshes; 5, Nipsells; 6, St Lawrence Bay.

Oystercatcher



Ringed Plover

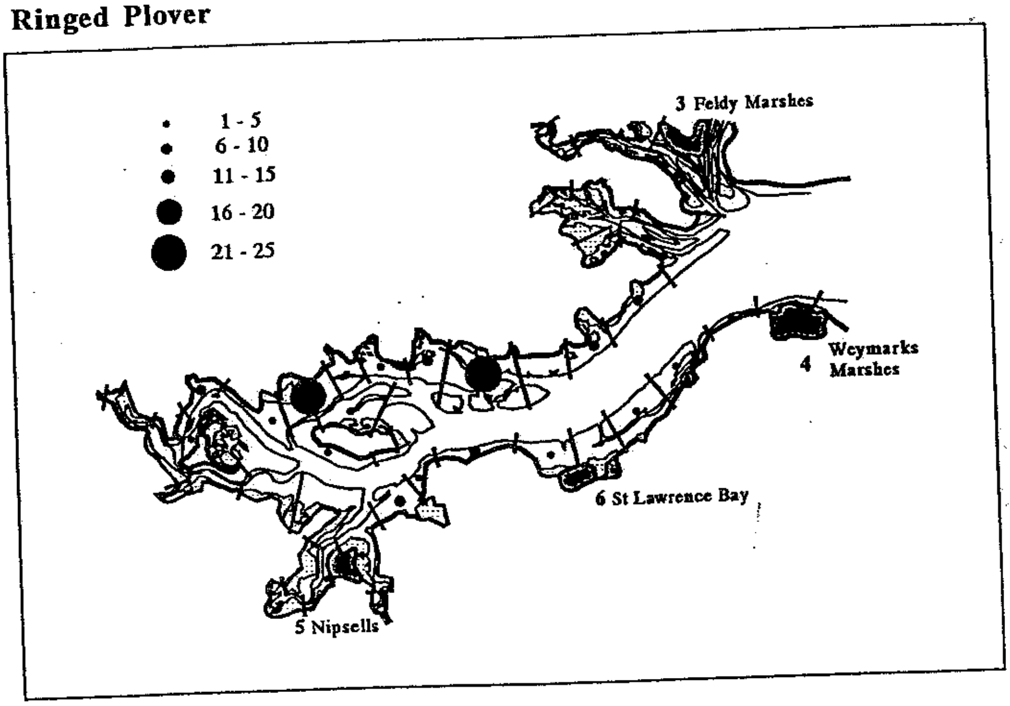
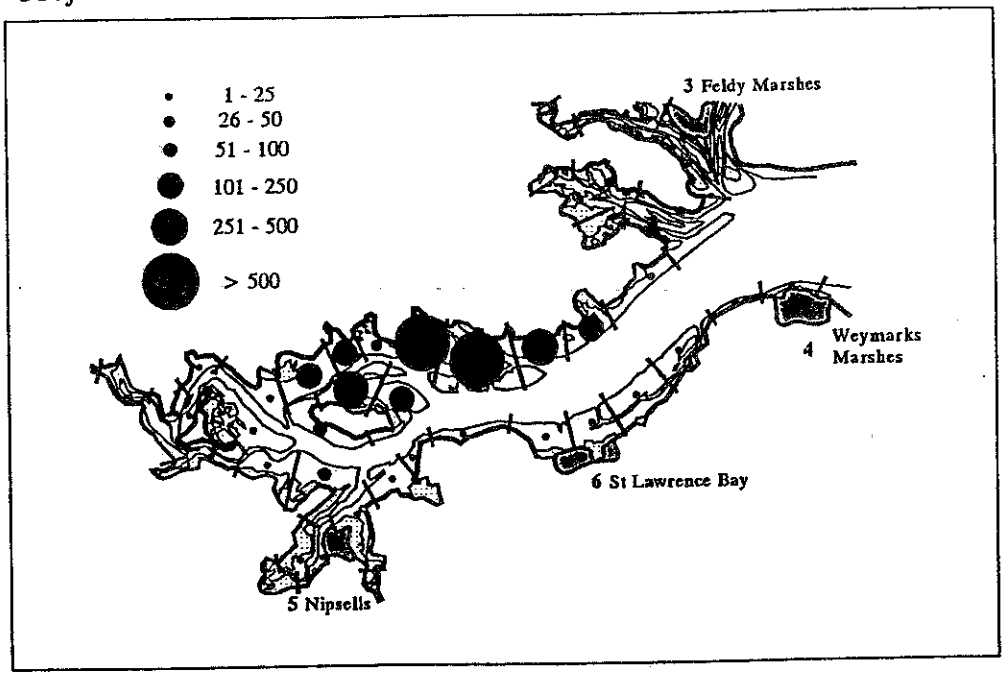


Figure 8.2.3 The average number of Oystercatcher and Ringed Plover recorded on each count area during the 1994/95 Low Tide Counts on the Blackwater Estuary. Shaded areas: possible compensation sites 3, Feldy Marshes; 4, Weymarks Marshes; 5, Nipsells; 6, St Lawrence Bay.

Grey Plover



Knot

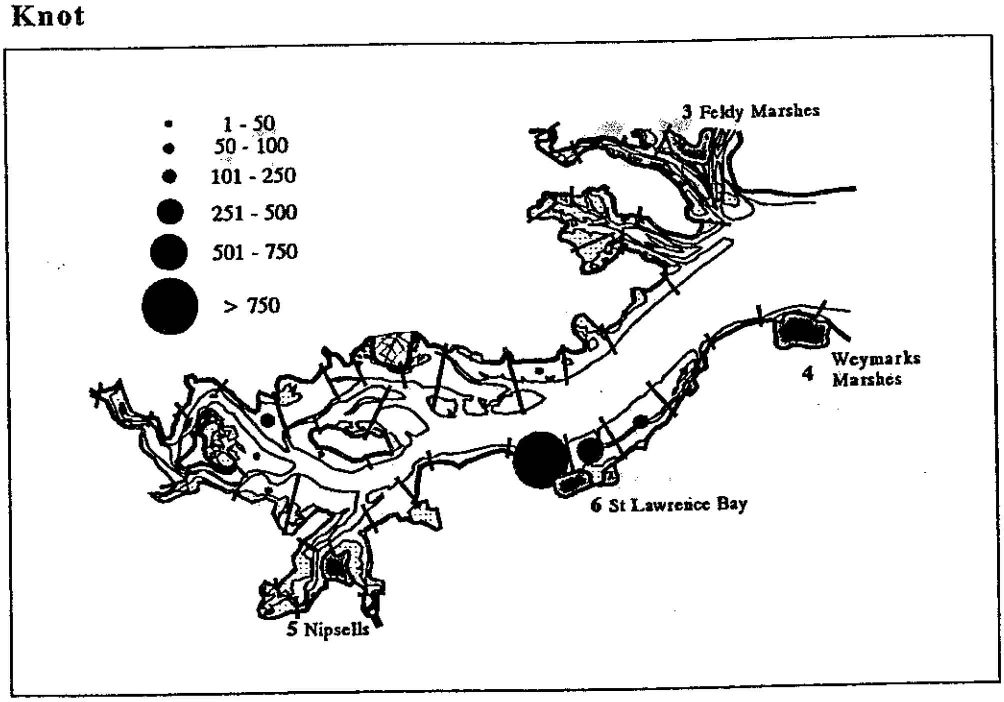
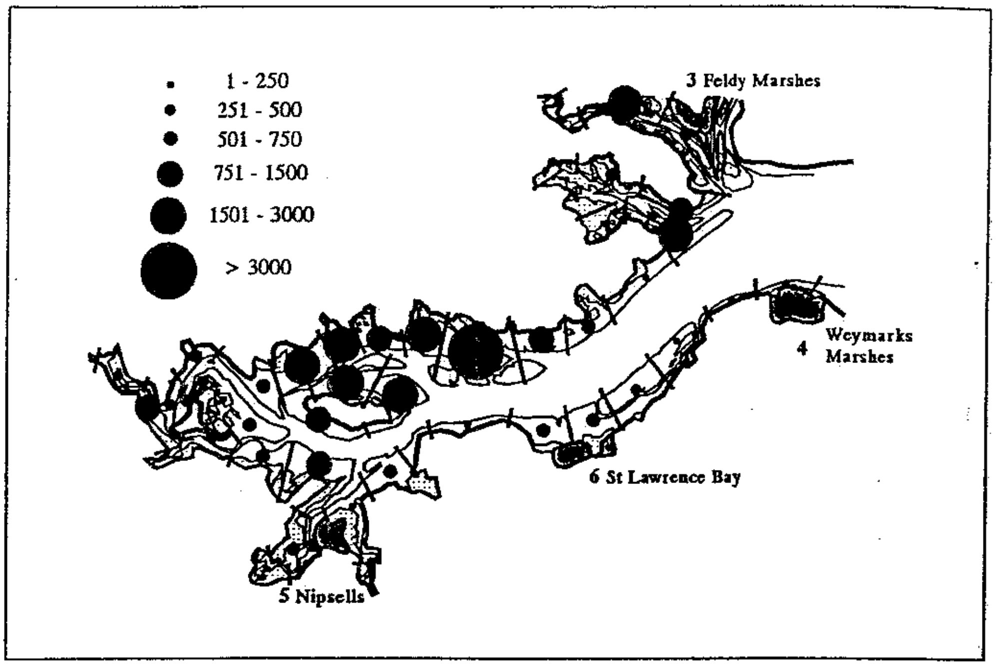


Figure 8.2.3 The average number of Grey Plover and Knot recorded on each count area during the 1994/95 Low Tide Counts on the Blackwater Estuary. Shaded areas: possible compensation sites 3, Feldy Marshes; 4, Weymarks Marshes; 5, Nipsells; 6, St Lawrence Bay.

Dunlin



Curlew

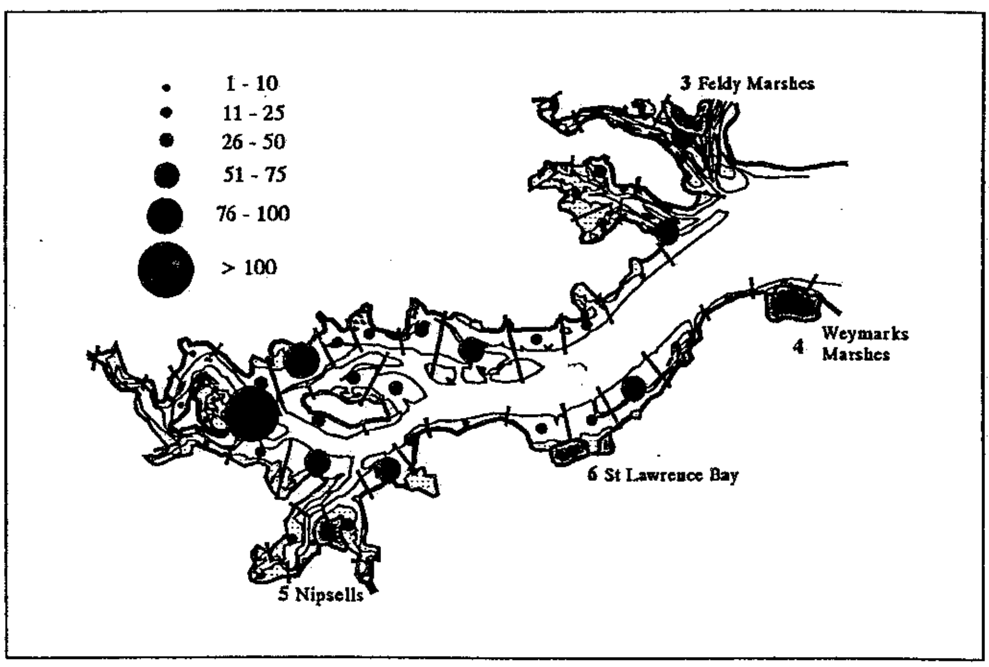
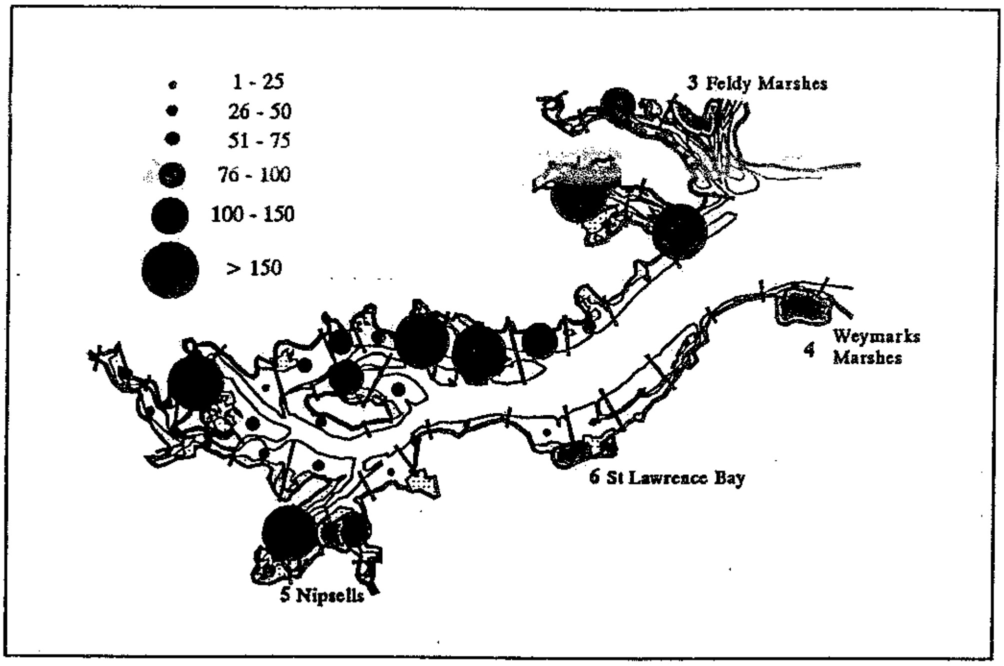


Figure 8.2.3 The average number of Dunlin and Curlew recorded on each count area during the 1994/95 Low Tide Counts on the Blackwater Estuary. Shaded areas: possible compensation sites 3, Feldy Marshes; 4, Weymarks Marshes; 5, Nipsells; 6, St Lawrence Bay.

Redshank



Turnstone

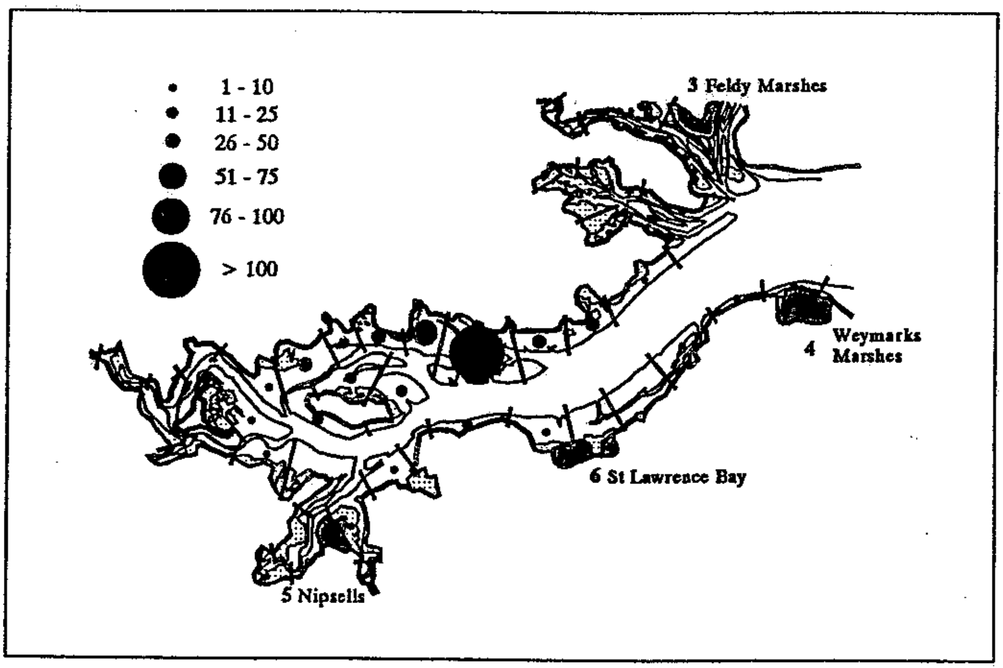
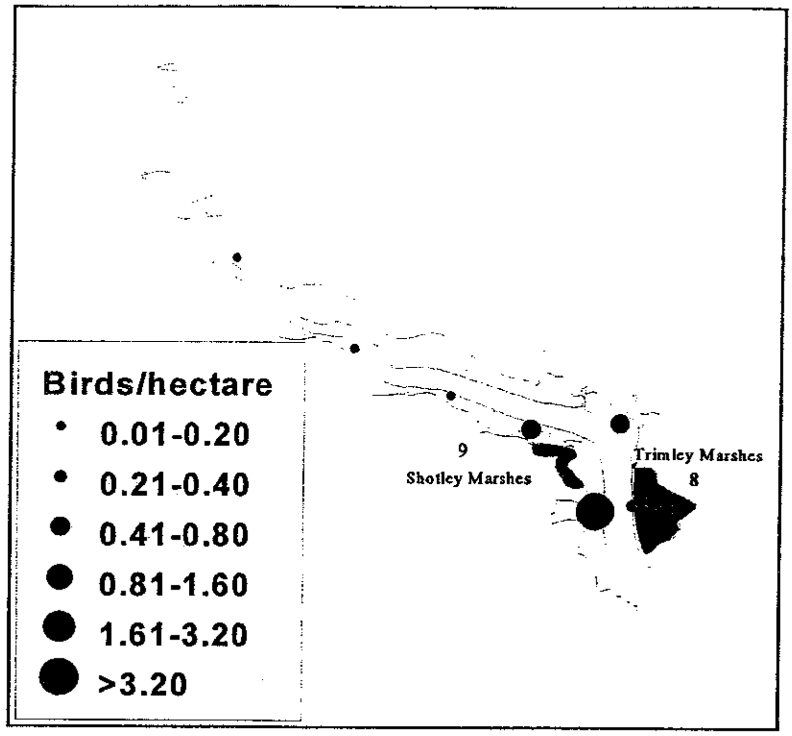


Figure 8.2.3 The average number of Redshank and Turnstone recorded on each count area during the 1994/95 Low Tide Counts on the Blackwater Estuary. Shaded areas: possible compensation sites 3, Feldy Marshes; 4, Weymarks Marshes; 5, Nipsells; 6, St Lawrence Bay.

Brent Goose



Sheldduck

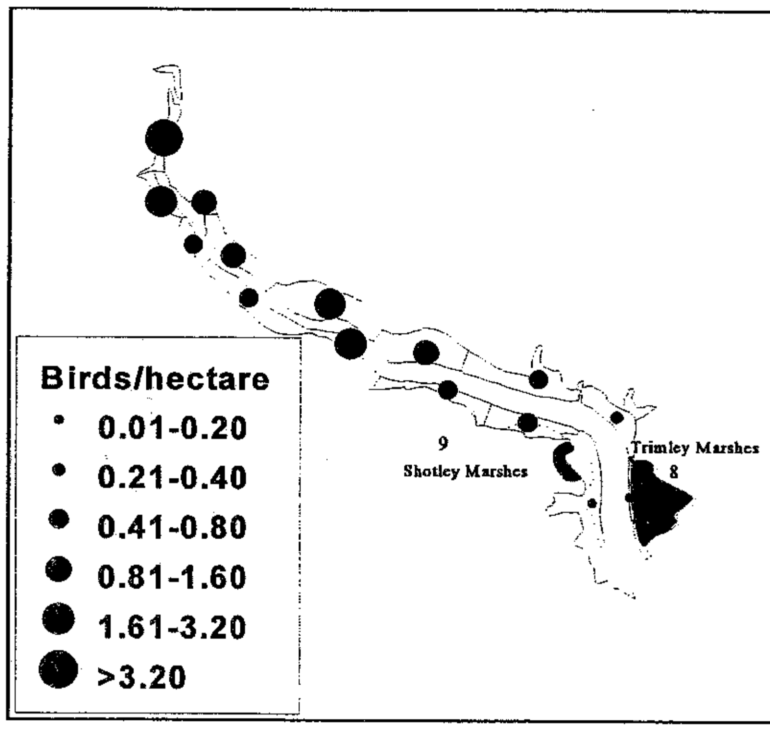
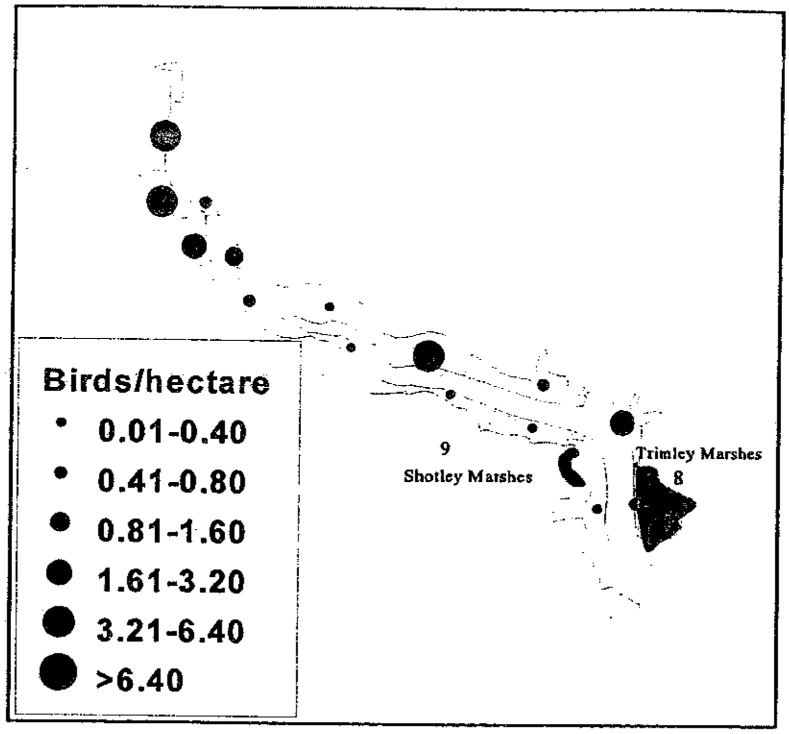


Figure 8.2.4 The mean density of Brent Geese and Shelduck on each count area during the 1996/97 Low Tide Counts on the Orwell Estuary. Shaded areas: possible compensation sites 8, Trimley Marshes; 9, Shotley Marshes.

Oystercatcher



Ringed Plover

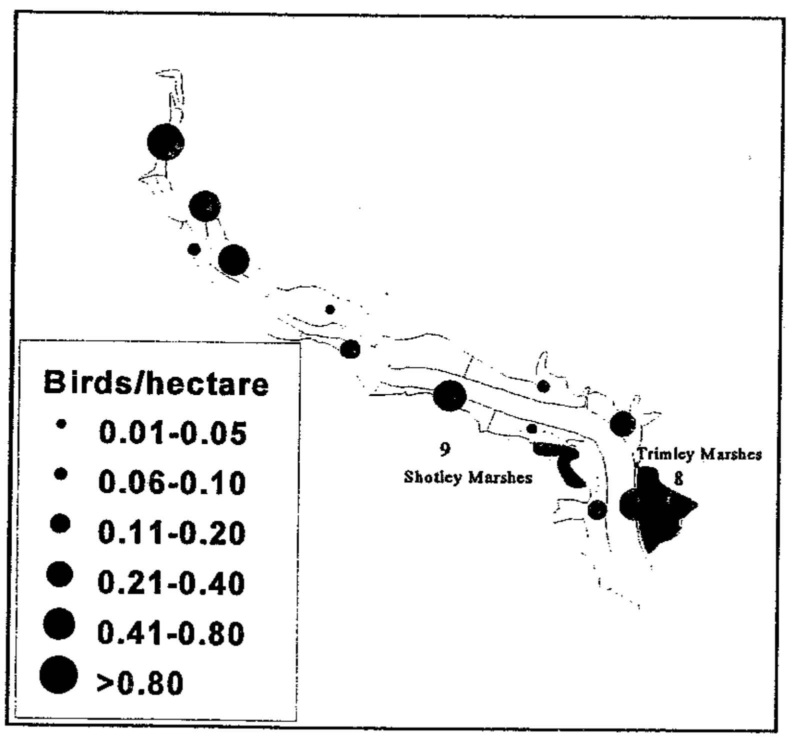
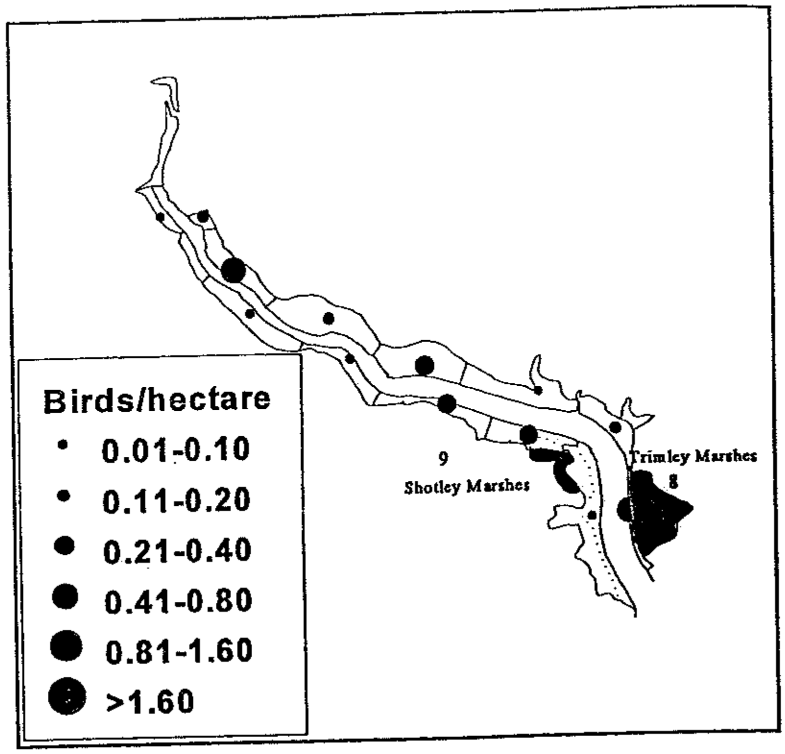


Figure 8.2.4 The mean density of Oystercatcher and Ringed Plover on each count area during the 1996/97 Low Tide Counts on the Orwell Estuary. Shaded areas: possible compensation sites 8, Trimley Marshes; 9, Shotley Marshes.

Grey Plover



Knot

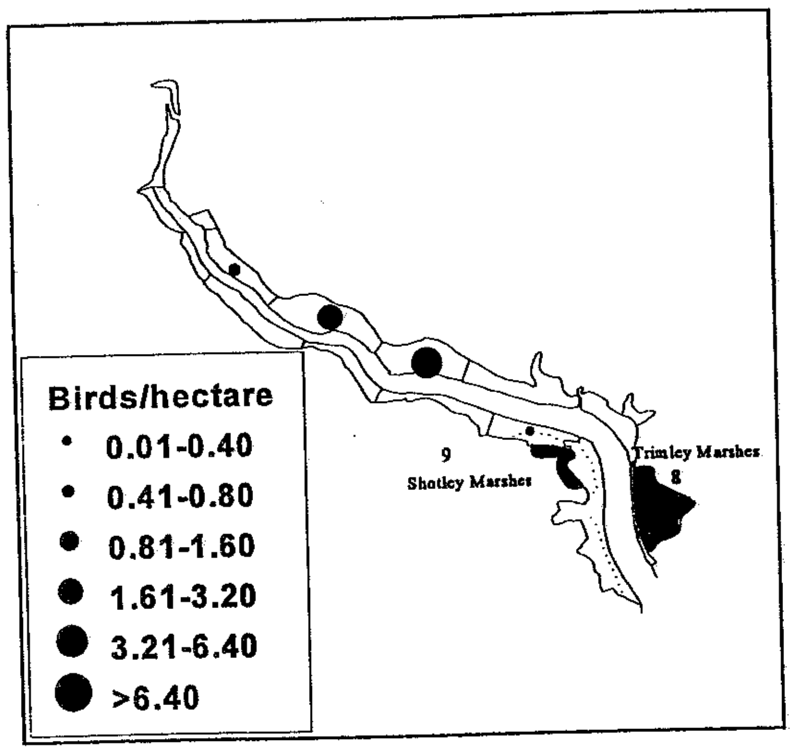
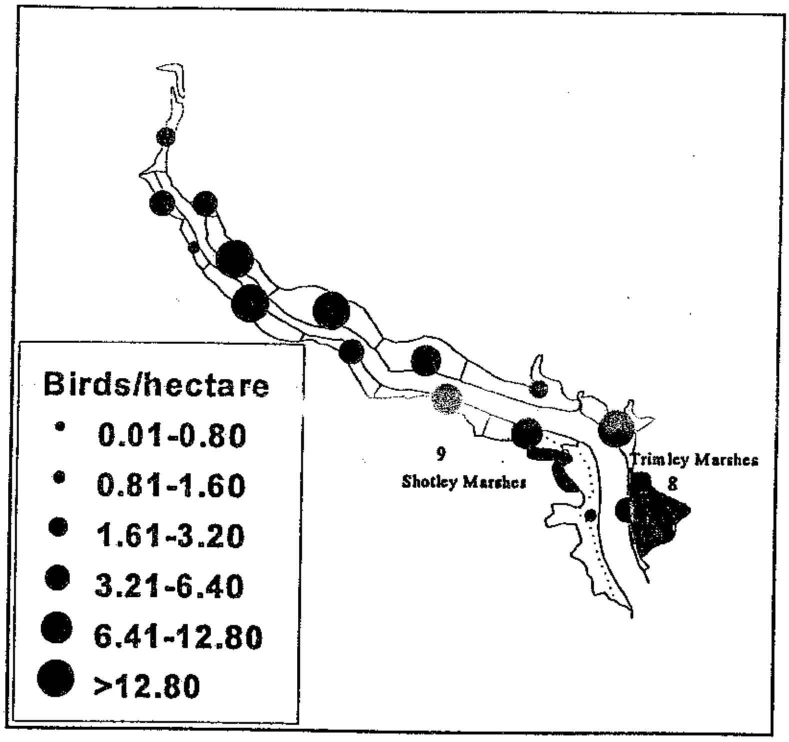


Figure 8.2.4 The mean density of Grey Plover and Knot on each count area during the 1996/97 Low Tide Counts on the Orwell Estuary. Shaded areas: possible compensation Sites 8, Trimley Marshes; 9, Shotley Marshes.

Dunlin



Curlew

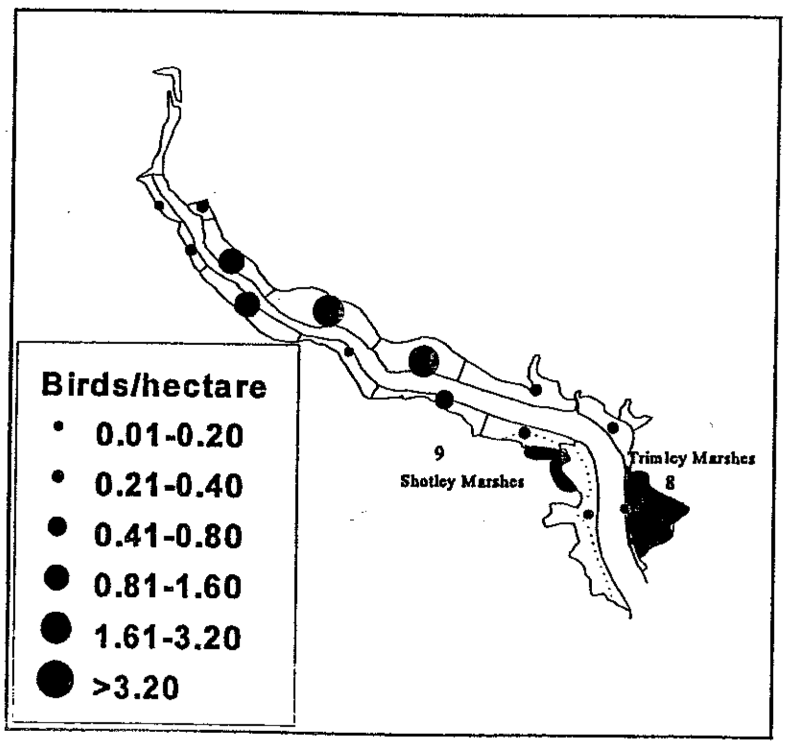
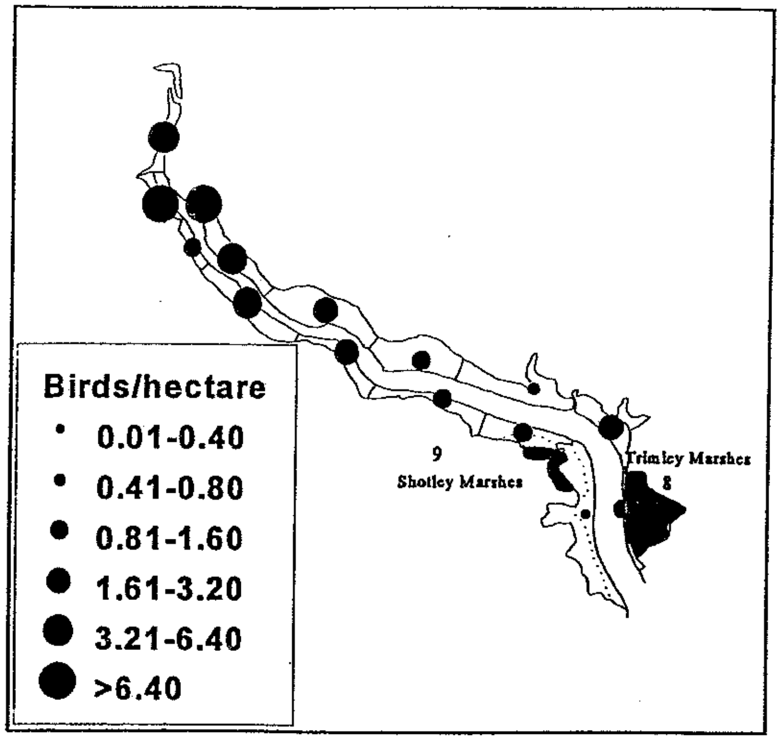


Figure 8.2.4 The mean density of Dunlin and Curlew on each count area during the 1996/97 Low Tide Counts on the Orwell Estuary. Shaded areas: possible compensation Sites 8, Trimley Marshes; 9, Shotley Marshes.

Redshank



Turnstone

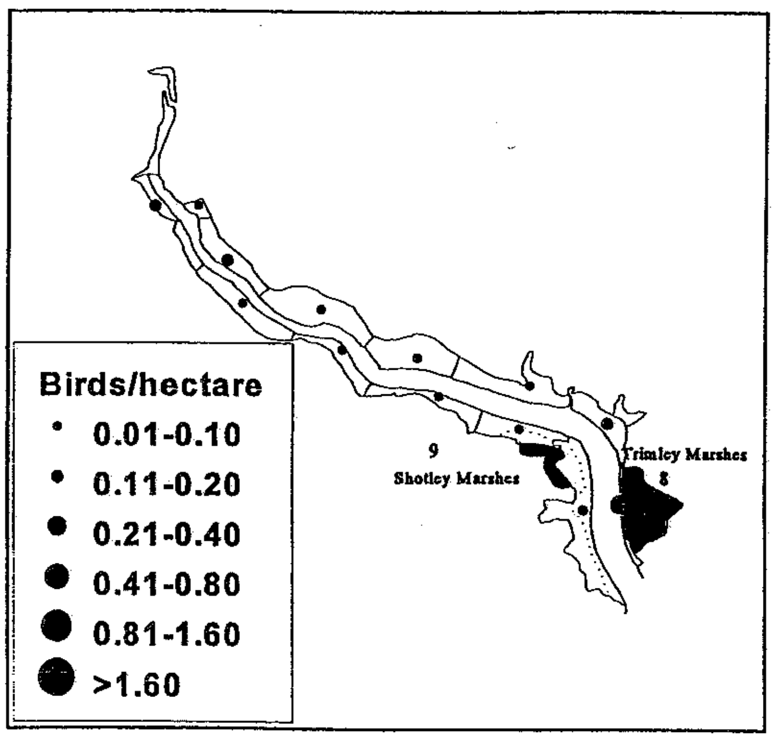


Figure 8.2.4 The mean density of Redshank and Turnstone on each count area during the 1996/97 Low Tide Counts on the Orwell Estuary. Shaded areas: possible compensation Sites 8, Trimley Marshes; 9, Shotley Marshes.